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The Emancipatory Potential of Ecological Economics: A Thermodynamic Perspective on Economics, Space and Sustainability[*]

Louise Takeda[**]

Abstract

There is a growing consensus that the modern path of development is leading humanity down a dangerously unsustainable path. Mass production and consumption have led to unprecedented changes in the natural environment while, at the same time, inequality is exploding both within and between nations. Until the recent rise of ecological economics, the sustainability concept has been largely restricted to economic criteria. However the physical aspects of material and energy flows often determine the actual ecological and social impacts resulting from economic activities. With this situation in mind, the following thesis examines the insights which a thermodynamically based ecological economics can contribute towards a new understanding and style of development, based on principles of ecological and social sustainability.

The thermodynamic principle is applied to three different theoretical approaches within ecological economics. The first approach focuses on the biophysical dimensions of economic activity. The physical insights revealed are then combined first with a world systems approach to development, and subsequently with a dialectical approach to spatiality and social life. Each of the approaches is used to inquire into different aspects of the complexities of the human-nature interaction, the roots of socially and ecologically unsustainable practices, and the economic, social or political responses necessary to move in a more sustainable direction. The engagement is largely critical and deconstructive, seeking to problematise many basic assumptions within the dominant neo-classical approach to economics and development, and put them into a new theoretical and strategic context.

The hope is that this paper can contribute, on the one hand, towards an understanding of the need for a thermodynamically based critique of political economy; and on the other hand, the need to firmly situate thermodynamic economic analysis within a broader framework of social and political power relations.

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Introduction

> As the social question dominated industrial society until the middle of [the last] century, so does the ecological question now occupy central place.
>
> (Elmar Altvater 1993: 230)

At the beginning of the twenty-first century, environmental issues are appearing everywhere as deeply contentious political issues. Since the early days of the industrial revolution, humans have mined the earth, stripped the forests, and filled the biosphere with an array of toxic wastes, all in the name of progress and development. While all living things take resources from nature and deposit wastes, humans have elevated this process to the point where numerous living organisms and whole ecosystems are no longer able to adapt. The depletion of energy and materials in the last half a century accelerated to such an extent, that more energy was consumed during those years than in the whole preceding history of humanity. While a few people have attained material abundance through this process, resource depletion and environmental degradation now endanger many and affect the future of all of us. In the past, belief in progress has allowed people to turn a blind eye to the negative effects of their decisions on others and on the environment. Now, in our global information age, it is becoming increasingly difficult to ignore the serious and increasing ecological and social threats which human societies are facing. The persistence of poverty amidst rising disparity between rich and poor, along with visions of impending global ecological collapse, are leaving more and more people wondering about the direction and wisdom of current developments.

An increasing number of people worldwide are realising that conventional modern development is leading humanity down a disastrously unsustainable path. Of course, with widely different economic positions, interests, needs, and aspirations, this realisation is not the same as a consensus on what needs to be done. In the meantime, nearly all nations continue to strive for more material goods. Whether these goods are essential for survival or trivial materialism is not an issue. Economic growth remains a main policy goal of all governments, and is seen as necessary not only to meet the welfare need of its citizens, but also to combat the growing threat posed by ecological problems. Dissident voices, who argue that economic growth within a global market system may reinforce rather than solve the conditions of poverty and environmental degradation, have been regarded as fairly marginal to the real issues- at least up until now. Serious attempts to come to terms with the issues underlying the current environmental crisis is calling into question some very basic assumptions within the ‘mainstream’ traditions of economics and development.

The following thesis examines the insights which a thermodynamically based ecological economics approach can contribute to an understanding of the complexities of the ecological impacts of human actions, the roots of unsustainability, and the direction towards a more sustainable path of development. Before introducing the basic premises of ecological economics and main focus of the inquiry, we will take a brief look at the concept of development and the mainstream approach to solving the environment-development dilemma.

1.1 The development debate - a short history

The concept of development holds within it a noble intention – it represents the hope that people all over the world will move towards reason and progress in an effort to improve the living conditions and welfare of all. The roots of development can be traced back to the European Enlightenment, but it was only after the second world war that development as an official plan was launched globally (Sachs 2000: 161). Both North and South were in agreement that development was positive and desirable. In its simplest version, development was seen to be a linear process, and contained an image which was decidedly European and American. Its initiators in the North saw it as a necessary condition for world peace, since economic upheaval following the great depression was seen as a major cause of the outbreak of war in Europe. In the South, after extended periods of humiliation during colonisation, development was seen as a way to join in with the modern world (Ibid. 162).

During the latter half of the 1940's and 1950's, various conceptions of development appeared[1]. While the concept is not necessarily synonymous with economic growth, conventional development is defined above all economically, where human welfare is measured primarily by the level of production. Signs along the development path include increased saving and investment, higher material productivity, industrialisation, urbanisation, use of modern technology and eventually high mass consumption (Sutcliffe 1995: 233). A catching up or modernising perspective has dominated development thinking, holding out the promise that developing countries could basically follow the same path as the developed countries. In addition, development has been largely perceived as mutually beneficial to both developed and developing countries (Hirschman 1981 in Ibid. 233). Development has thus been thought of as a positive-sum game where both developed and developing countries could get a bigger slice of the growing cake, even if the relative size of the pieces stayed the same. This modernising perspective, with economic growth as the core feature of development, has survived debates and analysis to this present day.

However, a central and controversial question revolving around the issue of mutual benefit has dominated much theoretical debate.[2] Supporters of mutual

benefit assumed that development would take place in basically capitalist economies, though there was disagreement as to the optimal level of state intervention. Some even concluded that development could take place in socialist systems, though it certainly was not considered a necessary condition. On the other hand, there were a number of theories which clearly rejected mutual benefit. While they differed on certain points, they all agreed that development in the South was not possible through a capitalist system and integration in the world economy. A compelling argument which gained ground in the 1960's was the idea that underdeveloped countries had been made underdeveloped by the success of the developed ones (Frank 1966). Rejecters of the mutual benefit perspective thus advocated some degree of disconnection from the world economic system as a requirement for development in Southern countries (Amin in Sutcliffe 1995: 234). They did not reject the goals of development as such, but believed an alternative socialist route was necessary to get there.[3]

While there were many areas of profound disagreement between rejecters and acceptors of mutual benefit, there were nevertheless some important points of agreement. Both sides, for example, saw development as desirable, and both agreed on a close connection between economic aspects of development, especially rising production and productivity, and meeting of basic needs and human welfare (Ibid. 237). In addition, while the obstacles to development were perceived very differently by the two sides, neither side considered that the limits of the physical environment might pose an obstacle to universal development. However, as the 70's approached, it became clear to many that none of these schools, in their original forms, were entirely capable of interpreting and explaining the causes and dynamics of (under)development. Moreover, not everyone shared positive associations with the process of development, and a growing critique of development arose.

Before proceeding, it should be said that conventional development has had some marked successes such as rapid economic growth, advanced technological progress, and increased levels of consumption, and has also diminished certain problems related to poverty in the South. Likewise economic growth in the North has, in some cases, contributed to an improved local environment. At the same time however, other problems have arisen and grown in severity as a result of development activities. For some, the problems caused by development appeared to outweigh the benefits gained.

Two broad critiques developed, which can be generally termed as the welfare and environmental critiques. On the one hand, the proponents of the welfare critique pointed out that development had not led to general welfare, and may overall produce negative consequences for human welfare. Such arguments were

supported by statistical evidence which revealed that the gap between rich and poor had widened; that poverty, hunger and disease persisted or had got worse; and that the majority of people in most Southern countries were living in greater hardship than at the time of decolonisation (Sachs 1993; Sutcliffe 1995). In addition, women, indigenous people, and small farmers argued that their basic needs and rights were either not met or were threatened by development. Concerns were also raised regarding the materially and culturally defined values and goals of modern development, which were seen to enhance unequal power structures and destroy non-western cultures (Shiva 1989; Sachs 1993). The focus turned towards grassroots movements and the empowerment of local people as a radical alternative to top-down development.

Still the ultimate challenge to the conventional development paradigm appeared to come from the environmental critique. The environmental critique pointed out in a very precise way the contradictory nature of development. It arose initially from a growing awareness of problems relating to such things as air and water pollution, electric fields, nuclear power plants, and pesticides. Then came the *Limits to Growth* report (Meadows 1972) which predicted the eventual exhaustion of the material resources on which development was based. The resources pointed to were primarily non-renewable mineral resources such as oil and valuable ores. However statistical data also revealed that since the 1950's, a third of arable land world wide had been seriously degraded, and around one quarter of tropical forests, fresh water and fish reserves had disappeared, in addition to the historically unprecedented rate of animal extinction (Sachs 2000: 166). These findings were followed by the discovery of the ozone hole, and concern over climatic and other environmental changes which suggested that the future of humanity itself could be under threat. The process of development, tied to the ideal of economic growth, appeared to be outgrowing the earth's capacity. Costs previously shifted to future generations, geographically remote areas, or less advantaged groups were beginning to affect the day to day lives of the Northern developed world. To a growing number, the rules which guided two centuries of economic growth appeared to be reaching their limit.

While all of these arguments had been present in economic debates for more than a century,[4] environmental concerns did not make much of an impact on development debates until the end of the 1980's. The response varied, from those who called for a halt to economic growth and a radical reorganisation of social life (e.g. Daly 1991), to those who argued that the environmental problem confirmed the need for more and rapid economic growth (World Bank in Sutcliffe 1995: 240). Others, who took biophysical limits seriously, still believed that environmental factors could be taken into account within a somewhat more complicated, but basically unchanged approach. Rather than seeing environmental problems and continuing poverty as signs of failure of economic

growth and development, they were taken up as challenges to be overcome by technology and good management.

1.2 Sustainable development and environmental economics

Environmental problems were once commonly believed to be solvable in isolation from social issues, but this changed with the arrival of the influential Brundtland Report (World Commission on Environment and Development [WCED] 1987). The report suggested that eradicating poverty was an important issue for environmental sustainability, and a new emphasis was placed on concerns over growing polarity of world income (UN Development Program in Peet and Watts 1995: 2). The report pointed out that poor people are often forced to destroy their immediate environment in order to survive. However, it did not go so far as to inquire into any political or economic interests which may cause or perpetuate poverty, or acknowledge that many poor peasants may be living in sustainable ways. Rather, poverty was regarded as a naturally occurring or an "original state of being" (Bryant 1997: 6), which eliminated the need to search elsewhere for its ultimate causes. Economic growth, along with population control, was therefore seen as necessary to help the poor escape "their" problem. Poverty thus became "the moral justification for advocating 'a new era of economic growth'" (WCED 1987 in Ibid. 7). Nevertheless, it was also acknowledged that a lot of current economic activity is unecological in its effect. Problems identified were basically the same as those named by the environmental critique, that is, that economic activity was causing pollution, using up scarce resources, disturbing ecosystems and destroying habitats. However, there was disagreement as to what the ultimate cause of these problems was. For environmental economists, environmental problems were seen to arise not as a result of economic activity as such, but rather due to the fact that many environmental goods are not priced.

Environmental economists, therefore, do not consider it necessary to radically reform the discipline of economics, and argue that its prime concern is already the study of the allocation of scarce resources. They do however call for a refinement of tools and methods, and greater attention to environmental inputs and outputs of the economic system (Pearce in Hayward 1995: 90). Environmental problems are seen as examples of "market failures", that is, cases where markets fail to achieve their otherwise predicted socially optimal result.[5] The central problem is that environmental goods appear to be provided for free, and therefore more of them are demanded than if they had to be paid for. The outcome of this overuse results in external environmental or social costs which are imposed on third parties – what economists euphemistically term "externalities". The first step to correcting this problem is then to calculate the market value or "shadow price" of these environmental costs and benefits (Jacobs 1997). This is done by defining the consumers' average willingness to

pay for benefits or avoid costs. Once the value of these external costs are defined, they can then be "internalised" or brought back within the market by raising prices of damaging activities through taxes, charges, tradable permits and so on (Ibid. 371). By using a single measure of monetary value, costs and benefits can be compared to one another. Assuming then that prices have been correctly calculated, total environmental damage will be reduced to the point at which marginal costs equal marginal benefits.

While this argument reveals some important deficiencies in conventional economics, not everyone has been convinced that the environmental problem can be solved by "getting the price right". For a start, there are a number of practical problems with pricing externalities, for example present values have to be assigned to unknown future costs, and the preference of future agents' cannot be known. Prices are also influenced by the distribution of property rights, income and power in social-institutional terms. For example, if people damaged are relatively powerless and poor (or unborn), then externalities will be valued lower relative to market goods[6] (Martinez-Alier 1996: 157). In addition, prices also reflect individual preferences, and therefore show a strong bias towards selfishness as opposed to collective preferences or the common good (Røpke 1999: 45). There are also many things we do not know and probably never will know about many environmental externalities, and of those we do know about, their effects may be perceived as positive by one group and negative by another. Moreover if values are given with reference to the ends the valuer has in mind, then whose preferences are to count? And can an interdependent ecosystem be divided into individual pieces which can be measured by price?

The list of problems concerning monetary evaluations goes on,[7] but there are also more fundamental questions of principle. For example can or should all things in life be valued in money terms, or are some things beyond exchange value? Can things of different sorts of value be measured and compared with one measuring rod? It has also pointed out that when societal decisions concerning the environment are based on conventional economic rationalising, a one-dimensional monetary value is applied to problems which are multidimensional in scale. Moreover, by reducing all things to their market value, the activities and processes that are not monetised or do not involve cash transaction get undervalued. Things in nature which are useful for production are considered to be of environmental concern, while all else falls by the way side. With such a range of concerns and false assumptions uncovered, Martinez-Alier concludes that "monetary values given to externalities appear as a consequence of political decisions which are themselves often based on spurious economic arguments" (Martinez Alier 1999: 31).

1.3 Ecological economics and implications of energy flows

In addition to political and social critiques, ecological economists argue from a more scientific nature that mainstream economic approaches have failed to understand the physical dimensions of ecological problems. Ecological economics arose in response to the inability of orthodox economics to adequately cope with ecological issues (Martinez-Alier 1999: 25). For more than a century, individual scholars have tried to introduce the issues addressed by natural science into economics, but have been systematically rejected (Martinez-Alier 1987). It was not until the 1980's, with the formation of the International Society for Ecological Economics, that ecological economics became recognised as an academic field of inquiry. Its basic premises are that the economy is embedded in the ecosphere and that the earth has a limited capacity for sustainably supporting people (Wackernagel 1999: 13). It encompasses diverse patterns of thinking with multiple disciplinary roots, which allows the "bigger picture" to come into view. Ecological economics can be described as "an attempt to correct the tendency for ecologists to ignore humans, and the social science world to ignore nature" (Costanza et al. 1997: 48). It is a system science which studies groups of interacting interdependent parts linked together by complex exchanges of energy, matter and information. This is in contrast to "classical" sciences which are based on the reduction of phenomena into isolatable events, and the search for basic "atomic" units or parts of the system (Ibid. 51). Costanza points out that while reductionist approaches are appropriate in cases where interaction between parts is non-existent, weak, or essentially linear, they are insufficient to understand complex living systems such as ecological and economic systems.

Among the major influences on the development of ecological economics were Howard T. Odum's *Environment, Power and Society* (1957) and Nicholas Georgescu-Roegen's *The Entropy Law and the Economic Process* (1971). Odum was concerned with material cycles and energy flow in ecosystems and produced one of the first energy flow descriptions of a complete ecosystem (Odum in Costanza et al. 1997: 59). Georgescu-Roegen is best known for his work on entropy and economics, and his theory continues to create controversy among economists, in part because it challenges strongly held beliefs about progress. Another influence was Kenneth Boulding's *The Economics of the Coming Spaceship Earth* (1966), which describes the transition from "frontier economics" where growth in human welfare implies growth in material consumption, to "spaceship economics" where growth in welfare can no longer be pursued through growth in material consumption. This view was further elaborated by Herman Daly (1977, 1991) and his work on steady-state economics, where he argues that the economy cannot continue to grow in a materially finite and non-growing ecosystem, and ultimately must reach some form of sustainable steady state. Finally, Richard Norgaard's (1994)

coevolutionary understanding of the unsustainability of modern society explains how development based on fossil fuels has allowed individuals to control their immediate environment for the short term while shifting environmental impacts to more distant places and future generations.

Despite these alternative paradigms, ecological economics is not a single paradigm based in shared assumptions and theory, and beyond the level of generalities there is no consensus of formalised principles (Wackernagel 1999). While the field has been deliberately kept conceptually pluralistic, there is generally a preferred paradigm used by individual ecological economists. The perspective of interest for this inquiry is based on the proposition that ecological economic studies must be grounded in biophysical assessments. While this is self-evident for some, it also contradicts a significant amount of work in the field (Ibid. 14). The starting point for analysis is the unidirectional and irreversible physical flows of energy from nature, through the economy, and back in degraded form (Rees 1999a: 31). Its thermodynamic foundation for economic activity points to the physical costs of the very act of production and consumption. This makes it fundamentally different from the market model of environmental economics. Understanding the physical/material transformations that bind the economy and ecosystems, combined with knowledge of complex systems theory and systems ecology, is seen as vital to resolve ecological problems.

A convenient and easily understood ecological economics tool for quantifying the human use of nature and assessing sustainability is the ecological footprint[8] (Wackernagel and Rees 1996). It measures the amount of biologically productive space necessary for a given population to produce the resources it consumes and to absorb the corresponding waste it generates. The purpose of the ecological footprint is to illustrate the possibility of exceeding biophysical limits or demonstrate its actual occurrence, and also to evaluate potential strategies to avoid it. In addition however, data from ecological footprint analysis also reveals the glaring inequality in the use of environmental goods and services by the North and South. At present, the wealthy 25% of humanity living in OECD[9] countries can be seen to occupy a footprint as large as the entire biologically productive surface area of the earth (Sachs 2000: 167). This means that whole countries survive by appropriating the carrying capacity[10] of an area of land vastly larger than their own physical territories (Rees 1999a: 36). Therefore while such countries appear economically prosperous in their trade balances and national accounts, they are running massive “ecological deficits” with the rest of the world (Ibid. 36). The problem of course is that in a closed space with finite resources, not everyone can be net importers of biophysical goods and services. The overconsumption of one party must necessarily be

compensated by the underconsumption of another if the world is to maintain some degree of ecological stability.

This has profound implications for development thinking. Previous development assumptions have assumed that economic growth in the North and South is the only practical means to alleviate poverty, address material inequalities between countries, and provide resources for resolving environmental problems. However with the global economy already running a massive hidden ecological deficit,[11] the amount of ecological goods and services available are inadequate to satisfy even present demand let alone increased demand (Sachs 2000: 167). To the extent that limited access to resources is a cause of poverty, the environmental overconsumption of the rich has an enormous bearing on the possibilities for achieving sustainable development.

1.4 Problem statement

The conventional stance of neo-classical economics maintains that development, primarily in the form of economic growth, will provide the conditions necessary to alleviate poverty and resolve material inequalities. However, after a half a century of economic growth, inequality has increased while the environment has been drastically transformed. It appears that the conventional vision of development, of access for everyone to the benefits of industrialisation, is lacking not only the necessary social and political basis but also the material base for its realisation. For many, this new reality marks an historical turning point in economic development, requiring a reorientation of goals and values, and a radical transformation of the way people relate to the earth and one another. In regards to this problem, this investigation asks:

> Can a thermodynamically based ecological economics provide the basis for an alternative understanding and style of development, which is both consistent with ecological limits and strives to ensure a basic level of wealth and resource equity?

In order to approach this problem, ecological theory will be combined with social and development theory. However, care must be used when applying an ecological perspective to political relations, since ecology can and has been used for different purposes. It has, for example, been equated with “lifeboat ethics” and “the survival of fittest”, and in the political arena, it has upheld hierarchical control as a “natural” state of affairs, or as a necessary means to safeguard certain aspects of nature. Therefore it is important to be clear about the main elements of sustainability in order to avoid such restrictive understandings. In the next section, the main structure, assumptions and arguments of the investigation will be reviewed.

2. Methodology

A frequently cited quoted from Harvey states that "all ecological projects (and arguments) are simultaneously political-economic projects (and arguments) and vice versa" (Harvey in Bryant 1997: 82). What this means is that ecological arguments are never socially neutral just as socio-political arguments are never ecologically neutral. If one accepts that there is no "value-free science" in relation to environmental and development issues, then it is essential to identify the values underlying a particular study. This applies especially to studies on sustainability, which inherently contain a normative element reflecting the particular sets of relationships which are of value to the author.

With this in mind, the three main elements,[12] considered to be essential requirements for the achievement of socio-ecological sustainability,[13] in this study are:

(1) ecological stability which requires that the natural generative and assimilative capacities of ecosystems/ecosphere are not exceeded by consumption and production of wastes by the economy;
(2) social sustainability which requires that society satisfy basic standards of material equity, and strive for a fair and equitable distribution of resources for all its inhabitants; and
(3) supportive socio-political institutions which requires that actions taken by institutions contribute to the potential, interest and diversity of people's lives without undermining their own productive abilities or independence

Each of these definitions is based on a set of assumptions or value judgements. In the first case, the definition of ecological stability is based on the assumption that the earth is a thermodynamically closed and complex system, where fundamental uncertainty is large and irreducible, and certain processes are irreversible (Costanza 1997). This takes into consideration the laws of thermodynamics, complex systems theory, deterministic chaos and systems ecology.

The requirement for social sustainability is based first and foremost on the ethical assumption that the wealthy do not have the right to appropriate a vastly disproportionate share of the world's finite resources. It is considered unacceptable that a quarter of humanity should live in abject poverty while another quarter lives in lavish material comfort. The argument put forward in the Brundtland Report is also relevant - that is, in a highly unequal world, the rich can be so rich that they do not worry about their own progeny having enough, and the very poor can be so poor that, at least in some cases, they will need to exploit resources and degrade the environment just to survive. In addition, social

sustainability is seen necessary to ensure future peace and security, since increasing disordering of regional ecosystems and the ecosphere can be expected to contribute towards the breakdown of civil order and increasing turbulence in the world political situation (Rees 1999a: 46).

Lastly, supportive socio-political institutions, as defined above, are seen as necessary in order to avoid a reductionist methodology which neglects social or cultural contexts and poses a threat to local communities and their lifestyles (Sachs 1993: 19). At a more basic level it questions whether modern institutions are themselves sufficient to meet the requirements of ecological and social sustainability.

Social sustainability and supportive socio-political institutions are social science concepts relating to the progress of human systems, and their requirement can be seen as broadly responding to the welfare critique of development. Ecological stability is based on scientific principles and its requirement can be seen as a responding to the environmental critique of development. While the welfare and environmental critiques overlap and share many arguments, they are also distinct from one another, both conceptually and in terms of the problems they identify and solutions recommended (Sutcliffe 1995: 241). For example, a certain understanding and process may provide a remedy for the environmental crisis, but fail to improve or even worsen the situation of the deprived. On the other hand, a process which strives to satisfy basic standards of material equity may, at the same time, increase stress on the environment, or destroy local cultures and communities. Therefore, these three requirements for ecological stability, social sustainability, and supportive socio-ecological institutions are presented together with the hope that a combined response to the welfare and environmental critiques of development might be found.

The structure for the theory section reflects three approaches within ecological economics for applying the thermodynamic principle to an understanding of human-environmental systems and interactions. The first section of the theory takes a purely physical approach to ecological economics based on thermodynamics. It focuses on the biophysical dimensions of economic activity, emphasising the material and energy dependency of all economic production and consumption activity with its physical environment. Three interrelated themes of primary concern are entropic irreversibility, environmental scarcity, and the problem of intergenerational economic justice. Overall, it provides an important critique of the failure of neo-classical economics to adequately theorise the biophysical basis of economic activity. In particular, it presents a strong case for entropic constraints to economic expansion, thereby challenging conventional economic growth theories.

While this thermodynamic critique of economic activity is extremely important, it is in itself not enough to take up the challenge of sustainability. It is also necessary to recognise that the transformation of physical materials and energy occurs through the medium of socio-ecological structures (Jacobs 1996:14). Therefore in addition to a biophysical understanding of economic activity, the sociological and political bases of economic activity must also be understood. In defining strategies to address socio-ecological problems, ecological economic analysis must be able to take into consideration injustices in terms of access to environmental resources and services, bearing the risks of industrial pollution, or the control over environmental management priorities. These are political and material problems related to social, cultural, and economic domination (O'Connor, M. 1994: 5). The question of who retains the benefits and who bears the costs is fairly obviously a matter of power. Therefore, in order to gain a more complete understanding of environmental problems and meaningful action concerning their resolution, ecological economics must be situated within a broader theoretical framework.

The second and third sections of the theory therefore present two approaches which combine the biophysical dimensions of economic activity with political ecology.[14] Political ecology, like ecological economics, integrates natural and social science approaches in an attempt to understand the relationship between human and ecological systems. However, in contrast to some forms of ecological economics, the concept of power is central to political ecology. As its name suggests, politics is of primary importance, and its rapid development since the mid-1980's can be seen as a response to the apolitical nature of mainstream approaches (Bryant 1997: 6). The classic definition of political ecology is that it combines the concerns of ecology and a broadly defined political economy (Blaikie and Brookfield in Ibid. 8). Political economy, unlike classical or neo-classical economy, situates the inquiry of wealth creation in a broad consideration of power dynamics of the social institutions involved in these economic processes (Bowles and Gintis in M'Gonigle 1999: 12). One of the primary concerns of political ecology is therefore the impact of unequal power relations on the nature and direction of human-environmental interactions. The combination then of ecological economics with political ecology provides the theoretical framework for understanding how the nature and direction of energy and material flows relates to unequal power relations; that is, how the thermodynamic principle operates at institutional and larger social/cultural levels (Ibid. 14).

One way to understand the role of power in human-environmental interactions is by focussing on the environmental result of these interactions, where the physical environment is seen as a manifestation of power relations (Bryant 1997: 13). This is the approach taken in the second section of the theory, which is

based on the ambitious attempts by Richard Adams (1975) and Stephen Bunker (1985) to quantify power in terms of control over energy flows. This is a very interesting approach in that it shows how unequal power relations may be 'inscribed' in the environment, both natural and human made, as well as in the resulting forms of social organisation and institutions. It takes as its starting point the internal dynamics of extractive and productive economies, and the interaction between them in a global market system, in order to show how systematic ratios of exchange and energy appropriation are at the foundation of modern industrial development and social hierarchies. By combining a world systems approach to development with an analysis of geographical flows of energy and matter, Bunker builds an ecological history of geographical uneven development.

This understanding of the social transfers of energy and matter in the creation of unequal exchange provides some very important insights into the problem of under/over development. There are however some deficiencies in the theory, corresponding largely to a post-structuralist critique of (neo) Marxist analysis. Its conception of power is insufficient to capture the many intangible forms of power and cannot, for example, explain how weaker actors may be able to resist or retain any power in situations of highly unequal power relations (Bryant 1997: 14). Moreover, the source of power is conceived mainly in economic terms, which disregards other manifestations of power occurring in a wide variety of material and non-material interaction. While the overall understanding of the creation of power through the appropriation of energy and resource flows is extremely valuable, a more inclusive understanding of power, taking in its multi-dimensional interplay with human-environmental systems, would be beneficial in order to facilitate more creative responses.

The third section of the theory, therefore, also builds on a thermodynamic critique of economic systems and political ecology, however its focus on power is expanded to consider the generalised dynamics of various modes of organising power. Sustainability is related to the growth and extension of centralist hierarchies of all types including but not limited to those sustained by market-based institutions (M'Gonigle 1999: 14). Its starting point is a dialectical understanding of spatiality and social life. Power is seen as having a geographic or physical component, which is largely consistent with a world systems analysis. However it is also seen as an "omnipresent tendency" which exists in the social consciousness and organisation of all things and acts of everyday life (Ibid. 17). The challenge then becomes to transform a range of centralist hierarchies which are unsustainably removed from people and places. Taking in post-structuralist considerations of space, knowledge, institutions, and development, as well as insights from regional planners, philosophical anarchy, and community-based development, this critical inquiry is open to a much broader area.

The goal however is not to elaborate a new universal theory for achieving sustainability, but rather to provide a kind of compass to orient future alternatives in a clearer manner. Different societies are quite obviously subject to different cultural and historical processes, and have different sets of economic and social practices (Schmidt 2000: 56). Therefore the general guidelines presented for understanding the roots of unsustainable socio-ecological development and possible alternatives to balance the tensions must be considered within a particular context, at which point appropriate forms of organisation or social action can be explored. This puts the inquiry into the broad category of "contextually-sensitive" theory (Thrift in Ibid. 56).

The overall methodological approach is clearly transdisciplinary, and takes into account theories and assertions from the social sciences, natural sciences and humanities. Combining disciplinary knowledge in this way is important, since the problems associated with sustainability (as defined for this investigation) cannot be adequately addressed within a single discipline or even separate disciplines. Transcending disciplinary boundaries in this way allows the problems associated with sustainability to be addressed in a more holistic manner. As Costanza notes, the problem is not with limitations themselves, but of limitations which are dictated by traditional divisions of subject disciplines rather than subject matter. This is not to say that the conventional disciplinary structure is not useful, but rather that a transdisciplinary way of looking at this problem can add important insights and address certain deficiencies apparent in existing approaches (Costanza et al. 1997: 77).

The following sections will present the three theories which are titled: 1) Biophysical Foundation of Economic Activity; 2) Energy Flows in the (Under)Development process; and 3) A Dialectical Territorialist Approach to Political Ecology. The theories will be followed by an examination of the ways in which these thermodynamically based understanding can be applied to address the main elements of sustainability defined for this project. The first part examines the relationship between society and nature, choosing a focus on space and time in order to show the incompatible development of ecological and economic systems, and point to the significance of a thermodynamic perspective for transcending the nature-society divide. The second part turns to examines the North-South relationship, and the importance of the theory of ecologically unequal exchange, based on net flows of energy and materials, for understanding underdevelopment. The last part takes a closer look at the usefulness of a dialectical territorialist approach, and its expanded awareness of space, in order to reveal the hidden forms of power and control within existing socio-spatial structures, and provide a spatial understanding which can empower and unite a wide range of resistances and social movements. Finally, the question, "Can a

biophysically based ecological economics provide an adequate basis for an alternative understanding and style of development?" will be reflected upon in the conclusion. The three applications of an ecological economics approach will be reviewed in terms of their ability to promote ecological stability, social sustainability, and supportive socio-political institutions.

3. Theories

3.1. The Biophysical Foundations of Economic Activity

1. Introduction to biophysical ecological economics

In recent years, there has been growing concern about the way in which economic analysis, as currently practised, is divorced from its biophysical foundations.[15] The standard view of the economy can be described as, "an independent, self-regulating and self-sustaining system, whose productivity and growth are not seriously constrained by the environment" (Rees, 1999a: 29). The underlying assumption is that all physical things ultimately consist of the same indestructible matter that is arranged in production, disarranged in consumption, and then rearranged in production. The economy is therefore envisaged as a closed flow from production to consumption to production again, where nothing is used up, only disarranged (Daly and Cobb 1990: 194). This standard view of the economy, as an isolated system, is in stark contrast to a biophysical approach to economics which recognises an intimate connection between the human economy and the natural environment. From this perspective, humans do not simply take out resources from nature or put back waste; rather all consumption and production processes are within nature as are humans themselves. Every activity which produces goods or generates services, can be described as a flow of material and energy which begins in the environment, passes through the humanised territory, and then eventually returns to the environment. The economy in this view can therefore be described as "an inextricably integrated, completely contained and wholly dependent subsystem of the ecosphere" (Rees 1999a: 30).

Biophysical ecological economics thus begins with a conceptual model that sees the economy connected to, and sustained by a flow of energy, materials and ecosystem services. In this view, industrial metabolism can be likened to biological metabolism where, like the internal process of all living systems which maintain themselves by continuously consuming a flow of materials and energy from their environment and discharging the wastes, the economy also consumes energy and materials from nature, converts the useful portion of it into manufactured goods and services, and discharges the wastes (Ibid. 30). It follows that economic transformations, like all such physical processes in nature, must be subject to the laws of physics. This issue has received great

prominence since the publication of Nicholas Georgescu-Roegen's (1971), *The Entropy Law and the Economic Process*.

Georgescu-Roegen defines economics as "the study of transformations in matter and energy brought about by human action and entropy" (Georgescu-Roegen in Beard and Lozada 1999: 124). Bioeconomics represents the culmination of his work in economics and thermodynamics. His greatest contribution could be summarised as: 1) pointing out that economics has been too physical in relation to human welfare - that is in assuming human welfare to be a function of production; but 2) not physical enough in terms of the physical nature of the economic process and what is required to sustain it (Lawn 1999: 5). His thermodynamic approach offers a conceptual framework to integrate a description of the human economy and its biophysical surrounding.

Entropy is a central concept for understanding ecological economics, and Georgescu-Roegen is often credited as the first to introduce the entropy concept into economics in a visionary way.[16] Entropy can be defined as the physical measure of the decline of usable energy (Faber 1996: 95). The term entropy, and the underlying concept, was introduced by Rudolph Clausius in the nineteenth century to help explain the tendency of temperature, pressure, density and chemical gradients to flatten out and gradually disappear over time. It is the physical law which explains, for example, why an ice cube melts when put in a drink. Entropy is involved in all processes, be it in nature or in economies, and is a quantitative measure for the irreversibility involved in any transformation processes of energy (Ibid. 95). Since it deals with available or useful energy it is, in Georgescu-Roegen's words, "the most economic of all physical laws" (Ibid. 105)

2. Thermodynamics and the economic process

The connection between the economy and the ecosphere has considerable implications for sustaining the economic process. In thermodynamic terms, all economic activity involves consumption and invariably contributes to the human load on the environment. By examining the unidirectional and irreversible flows of useful matter and energy from the ecosphere through the economic subsystem and back to the ecosphere in degraded form, thermodynamics can show the outer limits of what is physically and economically possible (Rees 1999a: 31). It is therefore argued by ecological economists, like Georgescu-Roegen, that the first and second laws of thermodynamics must be the starting point for a new approach to economics.

The first law of thermodynamics, also known as the law of conservation of mass/energy, states that mass/energy can be neither created nor destroyed (Ayres 1998: 189). With regards to mass, the law states that mass inputs must

equal mass outputs for every process. The economic implications of this is fairly straight forward, and implies that all resources extracted from the environment must eventually become unwanted wastes and pollutants. This however means, among other things, “that 'externalities' (market failures) associated with production and consumption of materials are actually pervasive and that they tend to grow in importance as the economy itself grows” (Ibid. 190). While materials recycling can help and certainly must play a role, recycling is energy intensive and imperfect, so it cannot fully compensate. With regards to the conservation of energy, the law says that energy inputs must equal energy outputs for any transformation process. This appears to lack practical significance for economics, since it seems to suggest that the use of energy will not reduce the amount of energy available to be used again. This is however not true. The reason for the confusion is that most discussions of energy are really about a certain kind of energy - that is available energy or "low-entropy energy" - which is not conserved (Ayres 1998: 199).

This reflection leads immediately to the Second Law of Thermodynamics which says that, “although the total amount of energy in an isolated or closed system will remain constant, the energy will tend to dissipate into less useful forms with every physical action or transformation that occurs inside the system” (Ibid. 190). This observation, that energy and matter are transformed in economic processes from a state of highly concentrated and easily available resources into a state of highly dispersed and non-available wastes, led Georgescu-Roegen to the assertion that the economic process is subjected to the Second Law of Thermodynamics. In his words, “the economic process is entropic: it neither creates nor consumes matter or energy, but only transforms low entropy into high entropy” (Georgescu-Roegen 1971: 281). A rise in entropy is associated with a decrease in the quality of energy available for future use, while a fall in entropy is associated with an increase in the quality of energy available for future work. Therefore, in spite of the circular flow model of the economy put forward by conventional economists, there is something permanently used up in the economic process. The stock that is used up refers to ‘low-entropy’ useful materials, such as fossil fuels or high grade metal ores which are dispersed to unusable concentrations over time. The stocks that accumulate include waste products, mine tailings, thermal pollution, and so on. These latter stocks are generally harmful, both to individuals through toxic effects, and to species and ecosystems through the loss of habitat (Rees 1999a: 31).

Daly and Cobb (1990: 195) use the following simple example of burning a piece of coal in order to illustrate the entropy concept:

> “When coal is burned, the energy in the coal is transformed into heat and ash, and the amount of energy in the heat and ashes equals that

> previously in the coal. But now it is dispersed. The dispersed heat cannot be used again in the way it was originally used. Furthermore, any procedure for reconcentrating this energy would use more energy than it could regenerate. In other words, the dispersal of previously concentrated energy would increase. There is no way of reversing this process. Burning a piece of coal changes the low-entropy natural resource into high-entropy forms capable of much less work."

This means that in any physical transformation, the quantity of raw materials taken from nature are equal in quantity to the waste materials ultimately returned to nature, but there is a *qualitative* difference between them. Entropy is the physical measure of that qualitative difference. From this perspective, Rees argues that "the ecologically important flows in the economy are not the circular flows of money but rather the unidirectional and thermodynamically irreversible flows of useful matter and energy from the ecosphere through the economic system, and back to the ecosphere in degraded form" (Rees 1999a: 31).

3. Entropic constraints on economic growth

One of the main economic implications which follows from the second law of thermodynamics is that, since economic processes utilise low-entropy raw materials and discard high entropy wastes, there are definite limits to economic expansion. The second law of thermodynamics says that work may be performed, but only by diminishing the amount of available energy for further work in the future. Energy used in the rearranging and recycling of material building blocks in production, is not itself recycled, and on each cycle some of the building blocks are dissipated beyond recovery. So while matter is not actually consumed, the capacity to rearrange matter is. As Daly notes, "We can do a better or worse job of sifting this low entropy through our technological sieves so as to extract more or less want satisfaction from it, but without that entropic flow from nature there is no possibility of production" (Daly and Cobb 1990: 196).

There are two basic sources of low-entropy energy: the solar, and the terrestrial or stored energy on earth.[17] An important difference between the two is their patterns of scarcity. Georgescu-Roegen pointed out that the total energy contained in all the world's coal reserves amounts to only about two weeks worth of solar radiation (Georgescu-Roegen in Beard and Lozada: 126). Sunlight, however, is limited in its flow rate to the earth, while terrestrial stocks such as minerals and fossil fuels can be used up at a rate largely of our own choosing. Since people are not able to appropriate sunlight, they exploit terrestrial sources instead. Industrialism with its intensified exploitation of fossil fuels and mineral materials, represents a shift away from dependence on the

relatively abundant solar source of low-entropy matter/energy, to the relatively scarce terrestrial source, in order to take advantage of the expandable flow rate at which it can be used (Daly and Cobb 1990: 196). In fact, the whole history of technological progress can be seen as a continuous substitution away from abundant sunlight toward increasingly scarce mineral resources. Daly notes, that "it was on the basis of this elementary consideration alone, that Georgescu-Roegen was able to predict, back in the 60's when most economists were talking about feeding the world with petroleum, that exactly the opposite substitution would happen: we would be fuelling our cars with alcohol from food crops that gather current sunshine"[18] (Ibid. 197).

As resources of low entropy are used up, the attempt to substitute them involves a greater expenditure of low-entropy energy and increase of high-entropy energy waste. This is a problem which cannot be overcome by technological means. Recycling, for example, involves fresh expenditures of energy in order to try and obtain useful energy/materials from a 'disorderly' mixture. But no matter how efficient a recycling process may be, there always remains a residue of waste air, water, and solids that can no longer be changed back into useful energy/materials. This points to the physical truth underlying economic concepts like production and consumption, and leads one to reconsider the real basis of material wealth and economic growth. For example, considering that the energy stored in fossil fuels has been concentrated by plant activity over thousands of years, the idea that consuming such resources yields economic growth seems rather foolish (Lee in Hayward 1995: 110). Likewise, many investments do not increase productive capacity in the physical sense, but rather increase the destruction of non-renewable resources.

Since matter/energy can neither be created nor destroyed, the material basis of all life and production processes is the qualitative difference between natural resources and waste, that is the increase in entropy. The bottom line is that low-entropy energy is necessary for production, and whatever we do, including recycling or the attempt to substitute, devalues energy/matter, and leaves less available for future processes. This scarcity puts limits on economic growth which are not surmountable even in principle. Therefore, based on the second law of thermodynamics, it can be concluded "that scarcity is absolute, not merely relative" (Ibid. 112).

4. Objections to resource scarcity and limits-to-growth

1) Resource substitution argument

The resource scarcity argument already received a fair deal of attention in the 70's following the publication of the famous *Limits to Growth - Report to the Club of Rome* (Meadows et al. 1972). The general conclusion reached by neo-

classical economists at that time was that resource scarcity would not limit economic growth in the long run, given continued capital investment and technological progress. In most economic growth models explored, it was assumed that human capital and natural capital (i.e. resources) are inherently substitutable and interchangeable, without limit (Solow; Stiglitz in Ayres 1998: 203). That is, while resources are considered necessary for production, the amount of resources needed for any given level of output can become arbitrarily small, approaching zero, as long as capital or labour are substituted in sufficient quantities (Daly 1996: 53). This implicitly assumes that extra capital and labour can be produced without extra resources. This led some prominent economists to the conclusion that "the world could eventually get along without natural resources" (Solow in Ibid. 53).[19]

In response, Georgescu-Roegen argued that natural resources are not like other production factor, but rather "are the very sap of the economic process" (Ibid. 53). Human-made capital cannot exist nor reproduce itself without the existence of natural capital. He argued that a change in capital or labour can only diminish the amount of waste in the production of a commodity, but that no agent can create the material on which it works (Georgescu-Roegen in Ayres 1998: 204). Daly in turn comments that "the neo-classical production function of labour and capital is equivalent to an assertion that it is possible to make a cake with only a cook and a kitchen, but that no flour, sugar or eggs are needed" (Daly in Ibid. 204). The reality however is, that regardless of the level of knowledge, capital requires low-entropy energy.

Nevertheless, some economists continue to argue their case for resource substitution. As a concrete example of the resource-substitution argument, some economists have argued that chemical pesticides are substituting for natural predators, thereby illustrating the point that human-made capital can substitute or provide a service equivalent to that of natural capital/resources (Cleveland and Ruth in Lawn 1999: 6). The point missed, however, is that chemical pesticides themselves require low entropy to be produced which can only be sourced from natural capital and which ultimately end up being absorbed by natural capital in the form of high entropy waste (Ibid. 6). Therefore rather than representing a substitution of human capital for natural capital, it is merely illustrating the preference of one form of natural capital over another. That is, chemical pesticides as humanly transformed natural capital, are being preferred over natural predators as raw natural capital. As Lawn argues, "ultimately, if the low entropy required to manufacture human-made capital does not exist, nor does the perceived human-made substitute" (Ibid. 6)

While a more in depth discussion of production functions or their implications are beyond the scope of this paper, it is of some interest to note that economists

in the late 50's were not able to adequately explain economic growth per capital in terms of changes in the two factors, capital and labour. Most of the growth in gross domestic product was attributed to "technical progress", which was essentially identified with increasing factor productivity or just labour productivity (Ayres 1998: 206) Ayres however points out that, "probably by far the largest part of the historical increase of 'labour productivity' that apparently drives economic growth is attributable to the vast increase in the exergy [low-entropy energy] flux per unit of human labour, supplied from the outside" (Ibid. 206). That is, low-entropy energy, in combination with machines, has in effect been a substitute for human labour in many sectors, thereby increasing labour productivity and, through linkages with wages and consumption, resulted in economic growth.[20]

From this perspective, the neo-classical tendency to ignore resources as factors of production means that it is not able to incorporate the basic thermodynamic reality that low-entropy energy is used up in the economic production process, but cannot itself be created or "produced" by human activity. While there is no fixed relationship between the monetary and physical size of the economy, economic growth has always implied correspondingly higher inputs of energy and materials. This connection weakens in advanced or post-industrial societies, though the absolute levels of resources typically consumed by a post-industrial lifestyle remains very high. This brings into question the export of pollution from richer to poorer countries, and the net import of raw materials and energy intensive commodities from poorer to richer countries. A biophysical approach therefore confronts growth theorists with these concerns and weakness.

2) The dematerialised economy alternative

Another response to the resource scarcity argument has been to point out that Georgescu-Roegen and Daly envision an economic system as a materials' processing system in which final products are necessarily material in nature (Ayres 1998: 204). While this is an accurate description of the economic system as it functions today, it is argued that in the future the economic system need not produce significant amounts of material goods. Ayres points out that in principle, it could produce final services from very long-lived capital goods, with very high information content, and non-scarce renewable sources of energy, such as sunlight. At the end of its useful life, a capital good in this hypothetical economy would be repaired, upgraded and remanufactured, but rarely discarded entirely. Therefore he argues that "there is no limit *in principle* to the economic output that can be obtained from a given resource input" (Ayres 1998: 204). It follows from this logic that there is no limit, in principle, to the degree of dematerialization that can be achieved in the very long run.

While such an approach does offers an important perspective for reducing material and resource consumption, Daly argues that it "expands a germ of truth into a whale of a fantasy" (Daly 1996: 49). Daly responds to such proposals, which he refers to as the "information reformation", with the following:

> "McDonalds will introduce the 'info-burger' consisting of a thick patty of information between two slices of silicon, thin as communion wafers so as to emphasise the symbolic and spiritual nature of consumption. We can also dematerialise human beings by breeding smaller people - after all if we were half the size there could be twice as many of us - indeed we would have to dematerialise people if we were to subsist on the dematerialised GNP! We can eat lower on the food chain, and we can be more resource-efficient, but we cannot eat recipes" (Ibid. 49).

There are fairly obvious technical and economic limits to efficiency in practice - food, cars and TV's cannot be completely dematerialise. Furthermore, Altvater points out that even a "virtual economy" has a material substrate, that is paper currency and what it represents. Moreover, it needs to be linked to physical communication systems, power supply lines, means of disposing waste products, educational institutions, transport systems, satellites and so on (Altvater 1994: 78). Rees also takes issue with the dematerialised economy alternative, noting that "it is purely a technical response to a systemic crisis, one that ignores social and cultural context and accepts unquestioned the fundamental values of the consumer society" (Rees 1999a: 45). He also argues that it ignores the present barriers, which would need to be overcome in order to seriously initiate action in this direction, such as the current level of public understanding, irreducible scientific uncertainty, the power of vested interests, and the large potential costs associated with required structural adjustments to the economy. Moreover, he notes that history suggests that spontaneous efficiency gains in the economy result in increased profits or lower prices, both of which lead to increased consumption and accelerated resource depletion, which economists call the "rebound" effect.[21] This leads to the realisation that achieving sustainability will require much more than a technological fix.

In short, while the dematerialised economy alternative is theoretically attractive, and will undoubtedly need to play an important role in any future sustainable society, it is not in itself enough to maintain a growing consumer society.

3) Solar energy - the future panacea

Another response to the resource scarcity argument goes on to consider the potential for utilising solar radiation. Ayres notes that the flow of low-entropy energy from the sun is extremely large and certainly adequate to sustain

economic activity in the solar system indefinitely, even though fossil fuel and metal ore stocks may eventually be exhausted (Ayres 1998: 189). He argues that while industrial society is currently based on terrestrial sources of low entropy, this is not necessarily a permanent condition. He notes that humans consume very little solar energy at present, except in the form of biomass, because fossil fuels are so cheap. However, photo voltaic cells are available which can convert solar low-entropy into electricity and, with improved technology, will become ever more efficient at doing so. Moreover, while the costs are considerably higher than fossil fuels at present, he predicts that costs will drop considerably as technology is developed and further production experience is accumulated. Therefore, he argues that even if we allow for a significant increase in future energy consumption, solar energy is not a scarce resource, and in the long run, the economic system is not dependent exclusively on the stock of low entropy fuels and mineral ores accumulated in the past (Ibid. 196-197).

Georgescu-Roegen however was quick to criticise, what he considered to be, overly optimistic assessments of new technological solutions such as solar power (Beard and Lozada 1999: 125). He argued that solar power technology is "parasitic", that is, requires greater inputs than it offers in outputs. He explained that first solar energy must be collected using collectors and other capital; secondly, the collectors need to be produced using solar energy and capital; and thirdly, capital equipment (used to produce the collectors) needs to be produced using solar energy (Ibid. 125). In short, the solar energy collected would need to exceed the amount used to fabricate the various equipment needed for its collection.

Ayres himself acknowledges this argument, commenting in a footnote that he is perhaps too optimistic in his assessment of solar power, since the creation of capital structure to harness solar low-entropy energy on a large scale would certainly require very large amounts of low-entropy energy from fossil fuels (Ayres 1998: 197). In addition, we cannot predict at what point the large scale utilisation of solar energy might begin to detrimentally effect other biospheric processes, such as the hydrological cycle, which depend on solar energy. Therefore, in short, while solar energy offers some very important advantages over fossil fuels, and will need to play an increasingly larger role in the future, it does not eliminate the reality of ecological scarcity.

Some would, however, still argue that it is at least technologically feasible to shift from non-renewable to renewable energy resources. Therefore, it is argued that ultimately, the supply of non-renewable natural resources is not the limiting factor for economic growth, prosperity, or human survival; and faith is subsequently placed in the future discoveries of science and technology to overcome biophysical constraints. The question however remains: if low-

entropy energy could be made available in sufficient quantities, through some future technological advance, would this allow current output levels to be sustained or even increased over time?

5. Entropic limitations on the sink-side of the economic process

So far, the arguments presented have focused on how entropy serves to indicate scarcity on the source side of the economic process. Entropy can however also serve to indicate scarcity on the sink side. Energy and mass conservation together with the second law of thermodynamics implies that unwanted by products or waste energy are inevitable in the course of economic production and consumption (Faucheux in Ayres 1998: 198). Waste or pollution which occur as a joint product of production and consumption corresponds to an increase in entropy. Basically, the more low-entropy resources that go into a process, the more high-entropy wastes that come out. The conclusion to be drawn from this is that all economic actions increase entropy. Since most of what leaves the economic process as waste cannot be used as an input to natural processes in the biosphere, this increase in entropy is irreversible. It follows that "for economic processes the availability of adequate environmental sink space for the radiation of high-entropy waste matter/energy is as important as the availability of low-entropy inputs"(Townsend in Faber 1996: 121).

Pollution of the environment with high entropy is a problem, even when taking into consideration the fact that the Earth can export some of the high entropy produced into the surrounding space. The mechanism for this is the radiation of heat from the Earth into space. However the amount of high-entropy energy which can be exported is limited, and if more entropy is produced on the Earth's surface (for instance by erosion, biological, ecological, economic or other processes) then "entropy waste" accumulates on Earth (Ibid. 132). An increasing rate of resource input and waste output (throughput) would therefore eventually exceed the rate by which the biosphere can assimilate the wastes, leading to degradation of the biosphere and disruption of the life-support services it provides (Lawn 1999: 7). The widespread and general disruption of the biosphere, which is currently being witnessed in the world, is evidence that we are already exceeding the limits of sustainable levels of ecological demand.

In response to this, various managerial approaches are taken in an attempt to manage the production of pollutants so that they do not exceed their critical threshold values. However, while techniques of abatement or disposal may reduce the pollutant in question, another kind of pollution generally results as a consequence of the additionally employed technique (Faber 1996: 131). Moreover it is assumed that we understand all the consequences the pollutants will have in the atmosphere, ground or oceans. However, this is a very unrealistic assumption, considering the complexity of the economy-ecosystem

interactions, and the very long time-scales of interests (Ibid. 132). In complex systems, there may be little warning before a system undergoes profound change, and no way of predicting the subsequent effects. Therefore Rees asserts: "Complexity and self-organisation theory thus undermine many prevailing assumptions about humanity's capacity to manage the ecosphere for sustainability" (Rees 1999a: 39). In this light it seems highly questionable that "objective" experts can determine the facts and decide what is best for us all.

To sum up, even if a large quantity of low-entropy energy became available, this might overcome resource limitations on the source side of the economic process, but could not overcome the limitations on the sink side. Furthermore, the availability of large amounts of "clean" energy would provide the means to increase production, which would lead to an increase in overall ecological demand and environmental degradation (Clow et al. 1998). And in practice, no energy source is pollution free, not even solar energy. From this perspective, it is not the finite resource stocks which are the main concern arising from human activity but rather the disturbance of complex and self-organised natural cycles. Therefore the desire for a new "self-sustaining" energy source which can allow for continuation of our current path of development is not only contradictory but also suicidal (Mesner and Gowdy 1999: 60).

6. Overall conditions for sustainable economic activity

Some of the weaknesses of mainstream approaches to development and the environment have been exposed using a thermodynamic perspective. While technical approaches such as the development of solar power, a dematerialised economy approach or improved control over pollution can help to alleviate some of the negative impacts of a high throughput economy, they cannot create the basis for continuing economic expansion. Ultimately, to achieve sustainable ecological processes, what is required is a limit on the rate of throughput and therefore a limit on the rate of material production and consumption. In thermodynamic terms, ecological sustainability requires that the rate of entropy production on earth is less than zero (Altvater 1998: 30-31). This means that in order for economic activity to be ecologically sustainable, the amount of low-entropy energy/matter which the economy consumes must be less than its production by the sun in nature. Likewise, when the economy has reached the maximum sustainable level of material throughput, flows rates must be held constant. Signs of stress on the environment, such as the loss of top soil, contamination of surface waters and oceans, acid rain, the hole in the ozone layer and global warming, indicate strongly that this point has already been reached. Therefore, attempts to maintain the current structure of economic growth will only deepen the current ecological crises and reduce potential future options.

7. From biophysical limits to political ecology[22]

Recognition of the biophysical limits to production and consumption is an important step towards understanding the current ecological crisis. However, entropic constraints to economic growth are still only half of the story. While the reduction of matter-energy throughput is certainly a central issue, the weakness of this argument is its ecological (physical) bias, with the result that many ecological economics analyses limit their focus to the identification of ecological limits (Luks 1999: 33). While ecological limits must certainly be analysed, equal attention must be paid to economic and distributional consequences of strategies aimed at sustainable development. This becomes clear when one considers, for example, the fact that Northern industrial countries use an enormous amount of non-renewable forms of energy in food systems compared with its use for all purposes in poor countries, yet it is only a small proportion of the total amount of non-renewable energy used by rich countries (Martinez-Alier 1987: 241). A prescription to reduce the throughput of energy and resources, without explicitly addressing the social and political issues underlying such drastic geographical differences in resource use, can result in strategies resembling neo-imperialism rather than strategies promoting ecological and social sustainability.

What is missing from the preceding ecological economics approach is an adequate account of geographical differences in resource use, as well as consideration of the particular contextual settings of people in terms of their cultures, societies, and economies. Human economic activity depends not only on the physical and energetic factors of production and consumption, but also on the social organisation to direct and extend human energies in the acquisition and transformation of natural resources. As Altvater points out, there is no natural necessity for atom bombs, and no natural law dictating how many people must drive cars. Rather these are questions of social and political organisation (Altvater 1993: 206). Therefore the physical insights of ecological economics must be supplemented with an analysis of the social and political dimensions of low-entropy energy appropriation. The study of ecological distribution conflicts within ecological economics can be distinguished as constituting the field of "political ecology" (Martinez-Alier 1999). This is in contrast to political economy[23] which focuses on economic distributional conflicts. However ultimately, any attempt to understand political economy and the mechanisms which generate inequalities in distribution, requires an examination of the ecological conditions of economic processes (Hornborg 1998: 128). Therefore, political ecology may be considered as providing additional insights to both political economy and ecological economics.

3.2 Energy Flows in the (Under)Development Process

The challenge for a biophysically based political ecology is to provide an analytical framework for understanding how the thermodynamic principle operates at institutional and larger social cultural levels. In order to do this, a useful starting point is an examination of the thermodynamic theory of open system and how it applies to human social systems. Georgescu-Roegen emphasised that production involves the transformation of matter and energy, and since neither can be humanly created, they must be extracted from a physical environment. Based on the second law of thermodynamics, all such transformations involve the conversion of low-entropy energy into humanly useless forms. From this perspective, any activity today is at the expense of activity in the future. The entropy law thus becomes a kind of metaphor of inevitable decline (Ayres 1998: 195). This view of development as continuous degradation is, however, in contrast to the observation that life on earth exhibits a tendency towards ever more structure and greater complexity (Baumgartner in Faber 1996:107). This is because the second law applies only to closed systems, that is systems that do not acquire or lose energy or materials. This contradiction can then be understood by distinguishing between open and closed systems in relation to the entropy law.

1. Society as a dissipative structure

The physicist, Erwin Schrodinger, noted that a closed or isolated system is characterised by a normal tendency towards disorder, as described by the entropy law (Faber 1996: 107). This would, for example, apply to the earth as a closed system, or the whole solar system as an isolated system. He pointed out, however, that all living systems in nature have to be described as open systems which, unlike a closed or isolated system, exchange energy and matter with their surrounding environment.[24] Open systems that are not in thermodynamic equilibrium are able to counter the normal tendency to disorder and maintain or increase their internal order by importing low-entropy energy from their environment and exporting high-entropy waste (Ibid. 107). This means that all living systems maintain their internal order by sucking order from their environment and discharging the disorder generated by their own metabolism. Because such systems feed upon and degrade available energy/matter from outside themselves, they have been called dissipative structures (Nicolis and Pirgogine in Rees 1999a: 32). This concept of open systems is relatively new, and still being formulated, but already offers a useful tool for describing economic or social systems.

The works of Richard Adams and Stephen Bunker are some of the most ambitious attempts to extend these interpretations from biological to social systems. Both have attempted to reformulate social theory through energetics, and subsequently characterise the roots of environmental destruction and uneven

development. Following Adams' theory of society, the evolution of humanity can be seen to exemplify the general principles of the energy dynamics of non-equilibrium open systems (Adams in Gare 2000: 279). Like all living systems, societies maintain their internal structure by drawing order from their environment and exporting disorder. Humans, however, have an inherent tendency to expand their capacity to exploit and transform the usable forms of energy within their environments.[25] Building on Adams theory, Bunker points out that while human intervention in the conversion of energy and matter accelerates entropy, it may also direct or embody energy and matter in forms which are both more durable and more useful, such as a factory or physical infrastructure (Bunker 1985: 33). This is possible since matter both stores energy and can be converted to energy. This then allows the normal tendency to disorder, that would characterise a closed system, to be countered. In addition, this conservation of energy into useful forms stimulates both production-enhancing modifications of the physical environment and increasingly complex social organisation (Ibid. 13). This in turn makes it possible to develop new and more powerful means of exploiting the environment, which in some cases involves the domination and control of other people to extend this exploitation. The bottom line is that in order for these socially and technologically complex forms of organisation to arise, vast amounts of energy must be available to be embodied or conserved in useful ways. In the case of cities or world centres, the goods or services which they require for their metabolism must be disembeded from their peripheral sectors (Yoffee in Hornborg 1998: 134). Bunker therefore argues that the analysis of energy flows between regions, and of the impacts of different uses of energy in different regional social formations, provides a much fuller explanation of development and underdevelopment than those provided by conventional economic models. This thermodynamic perspective reveals the social dimension of low-entropy energy appropriation, and forms the basis for a re-examination of geographical uneven development and unequal exchange.

2. The interrelation between extraction and production

To understand the uneven development which has occurred in different regions of the world, and to assess the prospects for long-term social and ecological development, Bunker's study examines the internal dynamics and necessary external relations between different social formations. Since the essential components of production, matter and energy, cannot be created, production requires some form of continued extraction from the natural environment. As Bunker (1985: 22) explains:

> "Productive economies are all, finally, only the molecular, structural, and spatial reorganisation of matter and energy extracted from nature. In the precise sense, humans can only produce ideas and symbols. The rest of what we call production is only our intervention in and

> redirection of natural processes of energy and material transformation."

Extraction and production processes are therefore integrally related, and as long as extractive activities are not in excessive amounts, and are spread across a wide range of species and minerals, biotic chains can reproduce themselves stably (Bunker 1985: 47). Sometimes extraction and production occur together in social formations bounded by a single regional ecosystem. However, usually extraction and production occur in distinct geographical locations. This is a tendency which has increased with industrial production, increased division of labour, and the resultant increase in social complexity, population density and urbanisation (Ibid. 22). Typically, some economies specialise in producing goods for internal consumption and export, while others specialise in particular extractive exports and depend on importation of transformed commodities for their own consumption. These productive economies correspond largely to the "developed" industrialised countries of the North, while the extractive economies correspond to the resource rich, but less developed countries of the South.

Previous explanations of the uneven development which arises with the geographical separation of extraction and consumption, have focused on labour as a standard of value for unequal exchange. A geographical transfer of value occurs when a part of the value produced at one location or region is realised in another. Emmanuel's theory of unequal exchange highlights the transfer of value which occurs from peripheral to industrialised countries due to very low wages in peripheral countries (Emmanuel in Martinussen 1997: 91). He argued that wages in peripheral countries are so low, in comparison to wages in industrialised countries, that workers are paid only a tiny fraction of the value of work they perform and the goods they produce. These wage differentials lead to inequality in international exchange, since industrialised countries are able to buy goods from peripheral countries at prices below the costs involved in producing the same goods in their own country. Exploitation of cheap labour is also an important mechanism for surplus extraction and the over development of the export sector in peripheral economies. Because of a large supply of cheap labour in peripheral countries, productivity increases do not lead to increasing wages, but instead to declining commodity prices (Muradian & Martinez-Alier 2001: 290). Markets for imported manufactured products or services, on the other hand, are more oligopolistic and gains in productivity in rich countries have translated into higher wages. Amin highlighted that after wages in core economies rose above subsistence levels, higher wages allowed for increased consumption capacity, which in turn enhanced returns to capital, thus allowing for expanded production of goods (Amin in Bunker 1985: 43). As a result of this

linkage between wages, consumption and profit, the core economies are able to accelerate.

While this explanation provides important insights into the causes of uneven development, from a thermodynamic perspective, it is apparent that the acceleration of a productive economy depends on something more: it requires the concentration and coordination of human and non-human energy flows. Georgescu-Roegen showed how conventional economic models of production ignore crucial energy transformations which occur between the extraction of material from nature and its use in industry. Production models are not able to incorporate the environmental costs of extraction and energy transformation, since the exploitation of natural resources uses and destroys values in energy and materials which cannot be calculated in terms of labour or capital (Bunker 1985: 47). Bunker's analysis therefore centres on the energy flows between regions and of different uses of energy in different regional social formations. Focusing on the history of the Brazilian Amazon Basin over 350 years, Bunker shows how extractive economies are "impoverished as they develop" through extractive enterprises which export their resources to industrial centres (Ibid. 23). At the same time, productive economies, which appropriate these resources for their industrial processes, develop economically and increase their power to dominate and exploit the peripheries. Bunker combines a world systems approach with an analysis of energy flows in order to build an ecological history of geographical uneven development. Through diverse case studies, he examines an ecological model which explains uneven development, unequal exchange, and regional subordination as a consequence of the physically necessary relations between extraction and production, and the resulting imbalance of energy flows between regional ecosystems. To understand how this comes about, it is important to understand the differences between the internal dynamics of extractive and productive systems.

3. Internal dynamics and differential incorporation of energy

The internal dynamics of extractive economies differ significantly from those of productive economies. Each develops very different patterns of location, residence, growth of economic infrastructure and environmental effects, and these affect the subsequent developmental potential of the affected regions (Bunker 1985: 22-27). While the specific characteristics and dynamics of particular extractive or productive economies need to be analysed individually, it is nevertheless possible to outline some general characteristics and tendencies in each.

One important difference is the effect that space has on extractive and productive processes. Bunker points out the increasing flexibility which productive enterprises have with regards to their location in space. They

typically locate in close proximity to each other, in order to build a social and physical environment shared by multiple enterprises. In this way, the costs of transportation, communication and energy transmission are shared by multiple enterprises, with the added effect that new enterprises can start up without needing to cover the total costs of the infrastructure they require. Because of their close proximity, the labour force at these multiple production sites is able to move easily between enterprises. The combined advantages of shared labour pools and shared infrastructure increase the ability of such production systems to adapt to changing technologies and markets. When individual enterprises suffer from technological or demand changes, they tend to do so at different times and different rates. This allows the infrastructure to which a declining industry contributes and the labour which it has employed to remain for subsequent enterprises.

In contrast to productive economies, extractive economies are largely fixed in geographical space and they must be located in close proximity to the natural resources they exploit. Since these resources are randomly distributed, their proximity to other enterprises occurs only by chance, and becomes less likely as the most accessible resources are depleted (Ibid. 24). This leads to isolation of extractive enterprises from one another making it impossible to share labour pools and infrastructure. Moreover, when extractive economies are far removed from existing demographic and economic centres, the costs of labour recruitment, subsistence, shelter, and infrastructural development substantially increases. Such cases may also involve migration of labourers, who are dependent on imported foodstuffs and other materials which are provided by the employer, thereby enhancing the control which the employer has over the labour force (Ibid. 26). Finally, as the resource is exhausted or no longer in demand, the infrastructure specific to the requirements of resource removal and transport lose their utility, as does the labour force which establishes itself at these extraction sites. The changes brought about in the distribution of population and in the physical environment, therefore, seldom serve any purpose to subsequent economies. When this point is reached, the economy of the exporting region is severely disrupted, resulting in a series of demographic and infrastructural dislocations.

Bunker also points out that the dynamics of scale in extractive economies function inversely to the dynamics of scale in productive economies (Bunker 1985: 25). In industrial systems, the unit cost of commodity production tends to fall as the scale of production increases. This is brought about primarily through the substitution of human energy for non-human energy. The falling unit costs accelerate production-consumption linkages, which permits the concentration and accumulation of infrastructure, and allows for expanded production systems. Industrial production therefore benefits from techniques which increase the

productivity of human labour through, for example, the use of fossil fuels. By contrast, in extractive systems unit costs tend to rise as the scale of extraction increases. This is because, as the scale of extraction increases, the amount of resource available for further extraction decreases. As resources become depleted, additional amounts of any extractive commodity can only be obtained by exploiting increasingly distant or difficult sources (Ibid. 25). Likewise, as extraction becomes increasingly difficult, the productivity of its labour progressively diminishes. This is particularly applicable to non-renewable resources, such as minerals and oil, but also applies, for example, to industrial agriculture where increasingly intensive techniques lead to soil erosion, nutrient depletion, and water pollution. The increasing cost of extraction eventually gives new locations or industrial substitutes competitive advantages over the original extractive enterprise. Unlike regional industrial economies, which can adjust to their own obsolescence by directing labour and capital to new products, extractive industries cannot unless there happens to be another resource in the vicinity which is in demand by external markets. Regardless, any new resource would eventually face the same predicament of depletion and exhaustion. As extractive resources become depleted, rising unit costs, further dispersion of labour and investment, and intensive ecological disruption eventually seriously reduce or eliminate these economies.

The ratio of labour and capital to value is also very different in extractive and productive processes. Bunker points out that extractive processes frequently entail a much lower ratio of both labour and capital to value than do productive processes (Ibid. 23). This means that the majority of value in an extractive economy is in the resource itself, and therefore profit occurs in the exchange itself rather than in the sector. Thus while extractive processes may initially produce rapid rises in regional incomes, this may be followed by equally rapid collapses when the depletion of easily accessible resources requires additional inputs of labour and capital without corresponding increases in volume. The rapidly rising cost of extraction once again stimulates a search for substitutes or new sources for extraction, and eventually leads to severe disruption of the extractive economy.

The implications of resource value and depletion become more pronounced when one considers the very different production times in extractive and productive economies. To avoid confusion, it should be noted that what is sometimes considered production, as in “producing” a certain quantity of oil, is actually more correctly termed, “extraction” (Martinez-Alier 1987). Actual production of natural resources takes place prior to its extraction by human labour, and in cases such as minerals, oil or top soil, production is over a time frame much longer than humans normally use. Bunker points out that if production is the incorporation of energy into matter, then industrial production,

in contrast to natural resource production, starts and ends at the same time as the labour that defines it (Bunker 1989: 591). From this perspective, it becomes apparent how resources which take thousands or millions of years to regenerate are traded, through international trade, for things that get produced on an on-going basis, resulting in a form of unequal trade. Furthermore, the additional value created when extracted materials are transformed by labour is generally realised in the industrial centre rather than at the peripheral origin of raw materials. These various differences in the internal dynamics of extractive and productive processes, and the uneven energy flows between them, provide an important understanding of geographical uneven development.

4. Energy, power and unequal exchange

From Bunker's study, systematic ratios of exchange and energy appropriation can be seen to be at the very foundation of modern industrial infrastructure. All infrastructure founded on an asymmetric exchange of energy between different social categories represents an appropriation of productive potential (Rees & Wackernagel in Hornborg 1998: 133). In relation to this problem of asymmetric or unequal exchange, the issue of power is central. This is because those suffering unfavourable rates of exchange are likely to have less power and, furthermore, the unfavourable rates of exchange tend to enhance these power differentials over time (Bunker 1985: 247). While the embodiment of energy and matter into more useful forms is most perceivable as physical infrastructure, at a more abstract level, it may also take the form of learning, complex social organisation, and technology. All of these result from previous uses of energy and matter, but make future uses of energy and matter more efficient. The social organisation, technology and specialised information and knowledge systems of advanced industrial societies can therefore be seen to have emerged from the vastly accelerated flow-through of energy and matter (Ibid. 45). The size and complexity of the modern state and bureaucratic organisations can also be seen to rest on accelerated and intensified energy use in productive economies, since energy intensification and the liberation of human labour from material production were both a stimulus to and a requirement for the increased flow of energy into the complex modern state (Ibid. 28, 39). This is not to say that energy and matter cause these developments, but that none of these can occur without the conversion of matter and energy. Since complex social organisation depends on the availability of energy and matter, and since social power depends on and is generated out of social organisation, the control of energy flows can be shown to generate social power (Adams in Ibid. 247)

In the case of extractive economies, economic and social development tends to be discontinuous in time and space, due to ecological disturbance and eventual resource depletion resulting from continuing extraction. As a result, the energy and matter taken from extractive regions does not flow through the extractive

economy, and therefore does not enhance social complexity nor remains embodied in complex social organisation. The organisational simplification which results from this loss of energy limits the amount of human energy which can be directed and coordinated, and this in turn limits the total amount of power which can be generated in a social formation (Bunker 1985: 247). In contrast, the accelerated energy flows through productive systems permits social complexity, specialised technical and social organisational knowledge in an increased division of labour, and coordination of research and development of new technologies (Ibid. 26). Technical innovation and powerful social organisational forms allows productive economies to change world market demands by freeing production systems from shortrun dependence on particular extractive commodities as they become depleted. This increases the productive economies dominance over extractive economies and their periodic disruption.

Unequal relations between extractive and productive systems can therefore be explained by the informational and organisational forms which can only evolve in energy-intensive productive systems, and which generate increasing social power and the technology to extend this power over wider geographical areas (Ibid. 35). Because of the discontinuous social development in extractive regions and lack of self-sustaining communities, they often lack the dense political and economic linkages necessary for local inhabitants to pressure the state to stop repeated disruption through extraction. As the social relations of extractive regions become simplified, and regional or local specificities disappear beneath the culture of industrialised societies, extractive regions become progressively less able to defend their own social and physical environment.

Hornborg adds that in order to understand “development” or modern technology itself, it is necessary to examine the way in which market institutions organise the net transfer of energy and materials to world system centres**.** As he explains, “Industrial technology does not simply represent the application of inventive genius to nature, but is equally dependent on a continuous and accelerating social transfer of energy organised by the very logic of market exchange” (Hornborg 1998: 133). All centres of civilisation must be able to appropriate from their peripheral sectors the goods and services which they require for their metabolism (Yoffee in Ibid. 134). In order for this appropriation to continue, it is helpful if it is represented as a reciprocal exchange (Godelier in Ibid. 134). As an example, Hornborg notes how the Inca emperor offered “chicha” or maize beer to the locals in exchange for their work in his maize fields. He points out, however, that the amount of chicha used to “pay” the labourers could only have represented a fraction of the maize harvest which the emperor gained from their labour, thereby illustrating the exploitative nature of the arrangement. It is in effect the same situation which can be seen to occur in modern market exchange, permitting the import of energy to industrial sectors. With modern

technology, however, the productive input that is being underpaid is resources rather than labour (Ibid. 134).

The way in which the export of entropy or extract of energy by industrial centres from their peripheries gets represented as reciprocal exchange is through the notion of market price. The notion of market price conceals that what is being exchanged are intact resources for products representing resources already spent. Hornborg explains that since industrial processes necessarily entail a degradation of energy, then the sum of products exported from an industrial centre must contain less energy than the sum of its imports. In addition, in order to stay in business, the finished products will need to be sold for more money than the amount spent on the fuels and raw materials used in their manufacturing. Hornborg points out that if a finished product is priced higher than the resources required to produce it, then "production" (i.e. the dissipation of resources) will continuously be rewarded with ever more resources to dissipate. (Hornborg 1998: 133). Furthermore, his research reveals that for any given set of fuels and raw materials to be used in manufacturing a particular product, the more that its original energy is dissipated, the higher the finished product will be priced, such that "the more energy dissipated by industry today, the more new resources it will be able to purchase tomorrow" (Ibid. 133). It is this logic, he argues, which has given industrial sectors, in the past few centuries, access to accelerating quantities of energy. The result has been both ecological destruction and global core/periphery inequalities.

The inequalities inherent in the geographical separation of the different parts of the total process of production can only be fully understood when the differential social and environmental costs to the various regions involved are accounted for. Seen from a thermodynamic perspective, the transfer of raw natural resources from extractive to productive systems must be regarded as one important element contributing towards underdevelopment in poor Southern countries. Conventional economic models cannot adequately explain uneven development between regions, since they focus only on production processes and ignore the environmental and social costs of extraction and the effects of uneven energy flows (Sustainable Europe Research Institute 2001). Unequal exchange however is created not only in terms of the labour value incorporated into products but also through the direct appropriation of rapidly depleted or nonrenewable natural resources. Therefore, the exploitation of resources and ecosystems along with the exploitation of labour and unequal distribution of monetary wealth must be considered as separate but complementary phenomena which affect the potential for long-term regional development.

5. From domination to social conflict

According to Bunker and Adams, there is an inherent tendency for humans to expand their capacity to exploit and transform the usable forms of energy within their environment. The conservation of useful energy forms makes it possible to develop new and more powerful means of exploiting the energy in the environment, which in turn gives some people more power to dominate and control other people to extend this exploitation. In the absence of self-sustaining and flexible productive systems, Bunker sees little or no economic basis for local opposition to entrepreneurs or national states that seek to exploit the population and environment of extractive regions. The hierarchies of power and control, associated with these developments, are seen to establish themselves both within a society and between societies, culminating in the present global system of capitalism (Gare 2000: 278).

The assumption is, that if this development path is not severely altered, expansion will continue until humans undermine the conditions of their own existence or society becomes so complex that it loses control of its own development. Bunker concludes that reversing such developments would require "not only an egalitarian human society, but also an egalitarian human society which sees itself as part of rather than master of the natural environment" (Bunker 1985: 254). Ultimately what is required is to slow the flow of energy to world centres. This would require a radical revaluation of nature, labour and community, along with efforts to reduce the interrelationships between the periphery and core zones in order to allow the peripheries to develop their economies more autonomously. Bunker is however, not very optimistic that such a society can ever develop, pointing out that humans in complex societies have so far applied their knowledge and foresights to increase their control over energy flows in ways which undermine the ecosystems that sustain them (Ibid. 254). Gare summarises this argument:

> "Developments in society, which increase the exploitation of usable energy and control of people to effect this exploitation, continue because it benefits those who have the strategic capacity to implement decisions to pursue these development. And such developments tend to increase the amount of usable energy they control, thereby further increasing their strategic power. Leaving aside issues of efficiency of use of energy or the proportion of energy devoted to expanding power to control people and nature, any community or society which attempts to preserve or establish an energetically less voracious, less environmentally destructive form of life will thereby be less powerful" (Gare 2000: 278).

Therefore, the more power an agent has, the more it will be able to effect changes that will increase its power. If such an analysis is correct, then the

power to create an alternative future will have to lie within the dominant structures of the core zones which control the greater flows of energy. It is in the regulative sectors of the wealthy countries that the power lies to control the energy forms and flows of other agents in their own society and in the rest of the world (Gare 2000: 281). The critique of "global ecology", however, argues that Northern-based scientific and bureaucratic elites are constructing global environmental issues in such a way that they steer away from difficult questions of structural inequality and differentiated interests towards techno-managerialist remedies (Sachs 1993). If continued social and environmental exploitation of the peripheries generates a global ecological crisis, the members of these powerful structures can be expected to shift the costs of the crisis to those without power. But, these costs cannot be held at bay indefinitely, and so it is only a matter of time before core zones too are faced with deteriorating conditions which threaten their own survival. As Bunker argues, "The ultimate collapse will be global not local. The continued impoverishment of periphery regions finally damages the entire system" (Bunker 1985: 253). If power derives from increasing control over energy flows, then it follows that those who attempt to reduce environmental destruction or who limit their use of usable energy, cannot survive and prevail over those who exploit the environment and other people to the destructive maximum (Gare 2000: 288). Bunker thus concludes that there appears to be little hope for societies, not bounded by regionally limited ecosystems, to achieve sustainable ecological and social development (Bunker 1985: 254).

While acknowledging the rich empirical insights which Bunker's study provides, there are at least two reasons to question his pessimistic conclusion: one is based on the notion of constraints, and the other on the notion of resistance. Beginning with the first, Gare argues that the theory of dissipative structures, as elaborated by Adams and extended by Bunker, is not a full account of the dynamics of ecosystems on which it is based (Gare 2000: 281-288). He points out that in ecosystems, where there is a constant source of energy, organisms only grow in complexity and size to a certain extent and then stabilise. That is, rather than continuing to dissipate increasing amounts of energy and expanding in complexity, ecosystems often reach a final steady state of complexity. This is due to the emergence of constraints which, as Gare explains, "emerge in ecosystems to both stabilise and enrich them, which to an even greater extent constrain the interaction between their components and between the organism as a whole and its environment, eventually limiting how much it can grow" (Ibid. 288). So while the theory of dissipative structures explains how the flow of energy can create new and highly ordered structures, highly ordered structures can persist to form "building blocks" for still higher levels of organisation (Ibid. 282). The development of such constraints are themselves energetic phenomena. If this idea of constraints is extended to social

dynamics, it requires that society direct energy to the development and maintenance of constraints which must prevent developments which would otherwise overwhelm them.

This connects to the second reason for scepticism regarding Bunker's conclusion: energy is not the only source of power in terms of controlling others or liberating oneself from the control of others. This is evidenced by the wide range of grassroots resistance movements which have successfully challenged or continue to challenge large, energy intensive, socially complex enterprises, in conflicts over the use of ecological resources. Martinez-Alier (1999: 26-37) gives several examples of this, such as the peasant community of Salinas which successfully prevented mining in their community; black poor populations in Esmeraldas, Ecuador, mainly women, which led the struggle against the destruction of mangroves by the shrimp industry; and the various indigenous populations of Amazonia which have fought Texaco and other foreign oil companies. There are also the well-known cases such as Chico Mendes and the rubber tappers in Brazil, and the Chipko movement in India. In addition, there are also a wide range of transnational alliance, networks, and social movements which are having important successes, such as the successful challenge to the Multilateral Agreement on Investment (MAI),[26] pressure on the International Monetary Fund (IMF) and World Bank for debt relief to highly indebted third world nations,[27] and extensive media coverage of anti-globalisation protests at high profile meetings of world economic leaders.[28] There are also a wide variety of local conflicts and resistances which may not warrant the term "movement". While these struggles are often practical struggles over livelihood and survival, they are often opposing more than the control of productive resources to include culture, ideology, and way of life. As Peet and Watts explain, "They contest the 'truths', imaginations, and discourses through which people think, speak about, and experience systems of livelihood" (Peet and Watts 1996: 37). These examples seem to suggest that there are indeed means by which local and less energy intensive forms of social organisation can defend themselves.

A weakness of Bunker's analysis therefore lies in his emphasis on structure, which tends to downplay the ability of politically or economically weaker grassroots actors to resist their marginal status (Bryant 1998: 81) Likewise, there is insufficient attention given to possible positive roles which local politics could play in mediating resource access and conflict. Furthermore, the apparent binary distinctions made between the social majority involved in extraction and the social minority involved in production are too simplistic. It is certainly not always possible to reduce the causes of poverty to extraction processes in a world system, nor is such an explanation sufficient to explain why certain disadvantaged groups have been more adversely affected than others have. So, while Bunker's analysis provides a useful characterisation of the geographical

power relations arising between extractive and productive economies, concerns over its tendency toward determinism calls for a more complex understanding of how power relations mediate human-environmental interactions.

3.3 A Dialectical Territorialist Approach to Political Ecology

1. Introduction

Within the field of political ecology some of the most recent work, regarding power relations and their effect on human-environmental interactions, have been drawing on a much wider range of theoretical sources than previous structuralist approaches.[29] Among the most insightful attempts have been those arising from a significantly different understanding of spatiality and social life. As Foucault simply put it: "Space is fundamental in any form of communal life. Space is fundamental in any exercise of power" (Foucault in Soja 1989: 19). Some of the earliest influential thoughts in the development of an explicitly spatialised political economy come from Henri Lefebvre, who asserted that space is not just an outcome of social relations, but that it is "an active, constitutive, irreducible, necessary component in the social's composition" (Keith and Pile 1993: 36). In Lefebvre's words:

> "Space is not a scientific object removed from ideology and politics; it has always been political and strategic. If space has an air of neutrality and indifference with regard to its contents and thus seems to be 'purely' formal, the epitome of rational abstraction, it is precisely because it has been occupied and used, and has already been the focus of past processes whose traces are not always evident on the landscape. Space has been shaped and moulded from historical and natural elements, but this has been a political process. Space is political and ideological. It is a product literally filled with ideologies" (Lefebvre 1976 in Soja 1989: 80)

Such an understanding draws our attention to the political nature of spatiality, since what appears as innocent "human geography" has the potential to hide various forms of asymmetrical power relations. Spatiality must therefore be seen as a means through which contradictions can be "normalized, naturalized and neutralized" (Keith and Pile 1993: 224).

This reassertion of space in critical theory has developed out of an encounter between Western Marxism and Modern Geography. A structuralist perspective has provided Marxist geography with a precise epistemological basis for examining the roots of spatial outcomes in the social relations of production (Soja 1989). In general, however, there had been little attempt to examine in more detail the connections between the social and spatial dimensions. Western

Marxists, on the other hand, led by such figures as Lefebvre and Gramsi, were creating a new critical tradition. Influenced by Hegelian idealism, they were concerned with questions of political culture, the powerful role of the territorial state, and the ontological supremacy of space over time (Soja 1999. 66). Among the novel ideas which developed was a large expansion of the sites of exploitation, and thus potential sites for mobilisation of class-consciousness. They argued that radical political economy needed to move beyond an exclusive focus on the point of production to explore the sites and social relations of reproduction, including those within the institutional structures which, ideologically and culturally, served to maintain and regulate capitalist social formations (Ibid. 66). The spatiality of capitalism and its institutional grounding was thus revealed to be not only economically contested ground, but also socially and culturally contested areas.

Within political ecology, an incorporation of such an expanded awareness of spatial relations and their connection to sustainability is presented in M'Gonigle's "Centre Territory Dialectic" (1999, 2000). Like Bunker's analysis, it examines the relationship between the character of institutional space and physical flows of energy through that space. However, while Bunker focuses on the social organisation which arises from extractive and productive processes connected through a world market, M'Gonigle expands this concern to examine the generalised dynamics of various modes of organising power. In accordance with the more recent writings of Gill and Frank (1991), it argues that sustainability or lack there of, must be related to the growth and extension of centralist hierarchies of all types, not only those sustained by market-based institutions (M'Gonigle 1999: 14). This stems from the observation that many centralised hierarchies, including the pharaohs of Egypt, popes of Rome, or Anglo-Saxon Kings, have arisen and been maintained without the existence of large-scale market exchanges. Therefore, rather than taking capitalism or the market as the basic focus of inquiry, it centres on the dynamics of hierarchical centralisation itself, and examines how these dynamics may be embedded in specific structures such as the market or other forms of social organisation (Polanyi in Ibid. 14).

The focus of concern, from an ecological perspective, is the directions in which energy, resources, wealth, culture, authority and power all flow. The core of the critique is the "consumptive pathology" inherent in social hierarchies of all sorts, including but not limited to those founded on market growth (Ibid. 15). This observation is based first on the general tendency for hierarchical systems to grow, due to ambitions and inequalities embedded within them; and second, on the physical flows of energy necessary to sustain them. It follows that, in order for hierarchical systems to grow, they must constantly acquire energy from systems external to themselves, and this eventually leads to the consumption and

demise of the territorial processes which they are reliant upon. This understanding challenges not only the character of capitalism or the market, but "the whole 'western' mode of historical and cultural development, from its faith in science and technology, to its dependence on economic growth, to its impact on traditional social and cultural systems" (Ibid. 14). This expands both the focus of critical inquiry and the range of possible alternative actions.

2. The dialectic of centre and territory

The essential characteristic of political ecology as political economy is its concern for spatial relations. However, the starting point for an assertive spatialised political ecology involves a reconsideration of space itself. Here a distinction must be made between physical (geographic) space and socially produced (institutional) space. Generalised physical space is the concept which has been incorporated into a materialist analysis of history and society, such as in world systems theory. The organisation and meaning of space, however, is a result of social translation, transformation, and experience (Soja 1989: 79-80). Socially produced space is therefore a created structure, comparable to other social constructions. Both physical and socially created space are focused on as important determinants of human relations in M'Gonigle's political ecology perspective. The physical aspect situates human institutions within varying degrees of connection to the natural world, whereas the institutional aspect situates human relations within varying degrees of hierarchical power (M'Gonigle 1999: 15). M'Gonigle then goes one step further to examine these spatial relations in a new dialectic which he calls "Centre and Territory".

Centre and territory are characterised as "two opposing tendencies or two idealised forms of social organisation that exist as a dynamic tension or dialectic in all human relations and societies"[30] (M'Gonigle 2000: 4). Unlike the simple bipolarity common to traditional class analysis, centre and territory cannot be reduced to concrete either/or dichotomies. Rather, its unique dialectical character arises from the complex interplay of the physical and institutional spatial relations[31] (Ibid. 4-5). At one dialectical pole, centre forms of social organisation are manifest in hierarchical organisation built around concentrated power, sustained indirectly by non-local resources. Examples of centre organisations include the productive industrial enterprise, as described by Bunker, as well as various forms of bureaucracy, corporate headquarters, or world cities. In contrast territorial forms of social organisation can be characterised as rooted in forms of social power which are dispersed and community-based, and maintained by local resources and direct production. M'Gonigle points out that this is not the same as "community" which is a complex mixture of both centre and territorial dynamics, nor is it captured by the geographical terms "regional" or "local". Rather, territory can be characterised as the "social/natural process of 'living in place'" (Ibid. 4). Furthermore, due to

their dialectical association, centre and territory are matters of degree. For example a large city, which is evidently a centralist form of organisation, may be more or less territorial depending on its spatial relations. From a geographical perspective, this would depend, for example, on how it uses resources, the extent of dependence on physical imports, internal use and distribution of these resources, and utilisation of its own internal resources through recycling and reuse. From an institutional perspective, it would depend on how equitable and participatory its processes of economic production and political decision making are, how stratified its internal production relations are, and how open and innovative its processes of planning and development are (Ibid. 5). Likewise the authority of a town mayor or aboriginal chief represents centralist forms of organisation, though their ways of governing may be more or less territorialist. Therefore territorial forms can be seen to permeate the most centralist structures, just as centralist tendencies exist in the most remote places.

The tendencies to social centralisation and organisational hierarchy, which have characterised the development of the modern world system, have resulted in an erosion of territorial forces and reinforcement of centrist growth. Evidently, centralist hierarchies can be sustained for long periods of time, assuming there is a sufficiently large territorial base to draw from. However, due to the nature of the physical flows of energy and resources needed to sustain hierarchy, continued centralist growth eventually destroys the territorial processes on which they depend (M'Gonigle 2000: 8). M'Gonigle points out that this is the basic contradiction that exists within all forms of centralist growth. It characterises countless advanced civilisations of the past which have fallen, just as it characterises the modern centralist-driven consumer society. From this perspective, the increasing social and ecological crisis which we are witness to today can be understood as "a diffused yet pervasive manifestation of centre over territory" (M'Gonigle 1999: 17).

At the same time, spatiality is an ever evolving process, which must be constantly reinforced, and when necessary, restructured (Soja 1989). This process of socially reproducing space, is a continuing source of conflict and crisis. The dialectical struggle between a hierarchical centre that draws its wealth from "afar and below" and a territorial community that sustains itself locally and within, is therefore a perpetual and unresolvable fact of social life (M'Gonigle 2000: 5). Thus, in the pursuit of sustainability, one must inquire into the means by which territorial forces can counterbalance socially and ecologically destructive centralist tendencies.

3. Territorial politics and the limits of state-based solutions

In order to better understand the current institutional context, it is useful to consider the historical background of the modern state and its centralist

tendencies. The rise of the modern state, from a historical perspective, has been achieved by the continual displacement of local cultures in order to gain control of new territories and secure economic flows to the centre, all the while, controlling potentially countervailing territorial forces (M'Gonigle 2000: 12). As the state has increased in size and complexity, it has directly absorbed higher levels of human and nonhuman energy. Bunker further elaborates on how the modern state and its agencies co-evolved with the progressive complexities, conflicts, and crisis of energy-intensive industrial production systems (Bunker 1985). As such, their operating procedures, complexity and size have corresponded to the high degree of economic differentiation, specialisation, and complexity of the industrial economy. Thus modern state systems are energy intensive institutional and organisational forms, and can only emerge in regions which have access to large amounts of energy and matter. This points to the anti-territorial force inherent in the design of the modern state, and reveals the limits to solutions that depend on continuing state-based regulations to constrain the very sources of economic flow which they themselves depend on (M'Gonigle 1999: 19).

From a territorialist perspective, the essential foundation of social and ecological sustainability rests on the protection and re-building of territorial forces, in order to develop an ecologically-based counter-balance to extractive centralist powers. This would involve the reinvigoration of place-based, democratic and co-operative forms of economics and politics to tackle the linear flows of energy and power (Ibid. 20). In analysing the history of Western institutions, this approach draws attention to a great variety of manifestations of centralist forces. M'Gonigle notes that greater decision making power by local people over their local resources challenges the autonomy of the global market system. While this does no in itself guarantee more ecological and equitable processes, it does at least remove structures in the state and economy that help to promote domination, thereby making widespread domination by a few more difficult (Hartmann 1998: 346). A huge diversity of social movements from feminists, to advocates of community-based development, to indigenous rights movements, already share in this common cause.

On the other hand, it is important not to simply equivocate territory with "good" and centre with "bad". Strong centralist institutions are necessary, for example, to confront the movements of multinational capital, ensure the intraterritorial respect for social justice, and maintain inter-regional equity. Local social organisation and economies can only develop autonomously and resist exploitative intrusions into their environment if they are protected by the state (M'Gonigle 2000: 13). Therefore, centralist hierarchy is legitimised to the extent

that it supports territorial non-hierarchy. This reveals the importance of exploring how centralist institutions may be re-designed to support rather than erode territorial values at all levels.

A territorialist political ecology points to a redirection for the centralist state, and a new progressive politics. M'Gonigle explains: "The redirection is to a great extent, spatial in nature, going beyond individual policies, programs and even legislative reforms to address a constitutional reconstruction that can begin to shift the dynamics of state power" (Ibid. 17). He notes that the beneficial transformative possibilities of more autonomous self-governing local spaces are rarely appreciated by centralist powers and largely unexplored by economists. Reflecting on the opposition often encountered by progressive forces to bureaucratic decentralisation, he notes that "territorial power should not be seen as a threat to political and bureaucratic authority, but as an alternative set of values and strategies to the wave of privatisation and corporatisation that is now the only avenue open for cash-strapped government in an age of neo-conservatism" (M'Gonigle 1999: 20). Unlike the wave of decentralisation being initiated by the political right to "fine tune" economic development, a territorial perspective points to the possibility for redirecting and transforming traditional patterns of economic growth. Elucidating what forms this re-designing of centralist institutions may take is a complex and culturally-sensitive challenge. M'Gonigle asserts that there is no single design for the ideal territorial institution, nor one preferred form of organisation. Nevertheless, the essence of a territorial model is the circular steady-state metabolism of physical territory with its embedded social community, along with the necessary institutional and cultural processes to sustain it (Ibid. 17). Furthermore, with a collective understanding of the socially and ecologically destructive behaviours of centralist forces, a territorialist society would necessarily foster self-reliance, egalitarian social relations, and ecological sustainability. This re-designing of institutions of central power to support territorial values may be an essential step towards a sustainable future.

4. Modern economics - science or social project?

An understanding of the entropy-generating nature of production and ultimate unsustainability of an expanding economy has already been elucidated, along with the call for the need to reduce the throughput in any growth-oriented, high-throughput productivist economy. For the purpose of achieving this end, there is a vast technical knowledge dealing with such things as improved resource efficiency, closed loop processes, clean production, and industrial ecology. All of these attempt to address environmental impacts in the basic design of production systems, rather than at the "end of the pipe". Such an understanding is also behind a wide range of technical-scientific innovations, such as ecosystem-based management, which takes a functioning ecosystem as the base

point for determining the level of sustainable economic and social activity, rather than the laws of the competitive market (M'Gonigle 2000: 11). At the same time, it is also important to recognise that vast flows of resources and energy are at the foundation of contemporary social wealth. Economic growth in the North has provided the basis for current levels of social equity and an average high standard of living, while in the South, economic growth is tied to the promise of progress and development. Therefore, reducing these flows will be a disruptive social objective. This points to the need to achieve substantive equity not only between states and regions, but between genders, races, and cultures, as a prerequisite for reducing the pressure for more unsustainable throughput (Ibid.).

In addition, addressing uneven resource flows requires consideration of the problems of the market mechanism. As ecological economists have pointed out, contrary to conventional belief, the market mechanism is not a circular but a linear process. Hornborg previously demonstrated the way in which markets create a colonising line of material supplies from territory to centre (Hornborg 1998). Because markets separate extraction, production, and consumption processes, resources tend to flow in one direction "to where the money is, to the North, to the cities, and to the wealthy" (M'Gonigle 1999: 23). Markets moreover demand the monetisation of all "commodities" which generate monetary flow, while denigrating things which do not have such value, whether that be biological diversity, a traditional way of life, or the interests of future generations. Through the process of economic globalisation, the competitive market mechanism expands its reach to facilitate the colonisation of centre over territory, both socially and ecologically, in countless ways. This colonising effect of the market is inherent in its very nature as a vehicle for the competitive exchange between producer and consumer for monetary value (Ibid. 22). This understanding of the market as essentially a flow mechanism is at the base of a territorialist approach to economics.

Market values, as a tool of economic assessment, must therefore be situated in a larger systemic understanding of economic power. From an ecological point of view, neo-classical economics must be situated within the powerful social project that has constructed the centralist institutional system that defines modernity (M'Gonigle 1999: 22). Norgaard's (1994) co-evolutionary paradigm helps explain how the spatial structures of the global economy coevolved with economic arguments rooted in the modernist premises of science: reductionism, mechanism, universalism, objectivism, and monism.[32] It also explains how conventional theories of economic development, along with the values, knowledge, and social organisation of industrialised social systems, coevolved around an energy-intensive, fossil hydrocarbon based economy. As a result conventional theories of economic development equate progress with processes

of modernisation and material growth. From this perspective, conventional economic theories of development can be understood as having been derived from positivist scientific understandings, and modernist assumptions of progress; and as such, have selected for individualist materialist values, favoured the development of reductionist understanding at the expense of systemic understanding, and preferred bureaucratic centralised forms of control rather than ecosystem-based management (Norgaard 1994b: 222). Such a coevolutionary understanding makes clear the socially-contextual nature of neo-classical economics, and allows its universal principles and claims of objectivity to be challenged.

In addition, modern exchange theory, based on reductionist and universal premises, assumes away distance and time (Altvater 1993). As a result, the evolution of economic organisations based on such economic explanations has increased the distance between consumption and production, and between economic action and their social and environmental effects. Market mechanism have facilitated the reach of urban organised power into remote resource pools and isolated communities, without reflection as to their costs. The rise of the positivist analytical frame of neo-classical economics can therefore be seen as providing an abstracted instrumental rationality for centralist growth and the construction of the modern institutional system, resulting in the unsustainable relations appearing today (M'Gonigle 1999: 22).

Whereas neo-classical economics has always claimed scientific status, many are now beginning to question the objective or "scientific" nature of economics, pointing not only to the various ecological and social critiques already mentioned, but also questioning "its rhetoric, its conception of the individual, its gender bias, its use of empiricism, and its construction of the history of economic ideas" (Mirowski; Milberg in Ibid. 22). Recognising the socially contextual nature of neo-classical economics, and challenging its claim to scientific status is an important starting point for ecological economics. This is however not a simple straightforward task, since as M'Gonigle notes, "On the one hand, neo-classism provides an abstracted, instrumental social rationality for centralist accumulation; on the other hand, the resulting structure of the modern urban/industrial world shapes the consciousness of its participants to accord with the assumptions of that rationality" (M'Gonigle 1999: 22). The positivist premises are so embedded in modern institutions, and so controlling of public discourse on economics, science and policy, that modern institutions have become blind to other patterns of thinking dependent upon other premises. Thus they are having difficulty discerning new visions and strategies to change the direction of development to a more sustainable course. As Norgaard points out, "It is not an accident that neo-classical economics addresses the piecemeal correction of resource and inefficiencies through improved markets, largely

ignoring the historical role of markets within a broader vision of viable relations between economies and the environment" (Norgaard 1994b: 222).

By contrast, ecological economics, with its inquiry into the thermodynamic foundations and costs of economic exchanges, marks itself as a paradigmatic challenge to this rationality. With its roots in ecology, ecological economics rejects the reductionism, mechanism, and universalism of the physical sciences, and acknowledges a natural world of interdependence, complexity, uncertainty, and interactivity (Funtowicz and Ravetz in M'Gonigle 1999: 21). Also, by combining the social and natural sciences, it explicitly situates human institutions within their natural context, giving a deeper insight into the human/environment interface, and hence, the roots of unsustainability. Moreover, a co-evolutionary approach recognises the importance of other patterns of thinking in order to understand the numerous unforeseen changes in environmental and economic systems, since how we understand these systems historically affects both our actions within those systems and efforts to re-design them (Toulmin in Norgaard 1994b: 216). This points towards the many important insights and benefits which could be gained by opening up to broader forms of knowledge.

5. Multiple knowledge systems, multiple possibilities

From an historical perspective, invalidating previously existing local forms of knowledge, patterns of social and political organisation, and methods of production has been necessary in order to justify creating imbalances in power and flows of wealth from territory to centre. This reveals one of the subtlest characteristics of centralism, that is, the particular and exclusive form of cultural knowledge that it embraces and attempts to enforce outwards as the "correct" way of knowing. As M'Gonigle points out, "understanding the tensions between centre and territory reveals a radical dialectic between competing ways of knowing, in particular, between the progressive social 'rationalisation' that has underpinned Western growth, and the knowledge systems of myriad cultures that have resisted their colonisation" (M'Gonigle 2000: 14). This understanding draws attention to a great variety of manifestations of centre power, for example the impact of writing-based over oral practices, traditional over industrial agricultural processes, bureaucratic laws over local customs, or patriarchal forms of authority over egalitarian ones (Ibid. 8).

Paradoxically, at the same time that "Western" thinking is spreading throughout the world, there is also an increasing recognition of the inherent limits to the positivist perspective which underlies both "normal" sciences and mainstream economics. These limitations are being demonstrated on the one hand by nuclear physics and advanced ecology, and on the other hand, by the negative environmental and social impacts associated with Western scientific,

technological, and economic development. Limitations are also increasingly evident in the realm of policy making, where decision makers are needing to make choices not just between conflicting sets of data provided by scientists and managers, but between different value systems (Funtowicz and Ravetz in Song et al. 2000). These conflicts between paradigms are essentially political conflicts involving competing authorities and knowledge processes.[33] Scientists trying to understand climate change, for example, are having serious differences in their understandings. One reason may be that they come from different disciplinary knowledges and cover different variables. However, some differences are matters of judgement rather than science, rooted in different beliefs in progress, different interests in material and environmental objectives, and different aspirations for the long run (Norgaard 1994a). For this reason, government agencies set up primarily to find out the facts, are finding themselves "hopelessly stalemated" by such competing rationalities (Ibid. 4).

As non-governmental environmental and social groups are questioning conventions and exploring new approaches, a broad territorial alternative to scientific thinking is being revealed. This includes a variety of "local" and traditional knowledge which are rooted in direct local experience which has sometimes been accumulated over generations, rather than in abstract universal theories and empirical methods more familiar to Western science[34] (Esteva and Prakash in M'Gonigle 2000: 15). While traditional or local knowledge has generally been rejected by Western science, sociologists have demonstrated that scientific technique (such as periodic testing regimes) is necessarily based on spatially and temporally limited observations, and as such, the understandings they reveal are often more limited than the traditional local knowledge which science has long rejected (Ibid. 15). Furthermore, when a single framework is applied universally without consideration of regional difference, it becomes susceptible to distortions in areas for which its pattern of thinking is least adequate.

Gradually though, some are beginning to accept that different cultures embody different ways of knowing, organising and interacting with the environment, and that multiple insights of multiple methods ultimately expands the possibilities for viable forms of community, knowledge, organisation and technology (Norgaard 1994a). Of particular relevance to a territorialist perspective, are the insights that may be gained from knowledge and systems of management existing in diverse small-scale, less consumptive and self-managing systems. This includes both traditional forms of sustainable management, and emerging precedents of community-based forms of social organisation and "best practices". There is much to be learned from sustainable practices found in non-industrialised cultures, as well as from many sub-cultures within the industrialised countries. However, in order to benefit from these different types

of knowledge on a wider scale, innovative processes need to reallocate decision-making power to represent different viewpoints.

3.4 Summary of Theories

The over-exploitation of ecosystems and rising economic inequalities in the world have become central issues to be addressed in the endeavour to achieve sustainability. Mainstream explanations of ecological problems tend to favour themes of poverty and population growth, while the issue of economic inequity continues to be defined as a problem of the poor. Limits to economic growth are seen as imposed not so much by nature as "by the state of technology and social organisation" (WCED in Rees 1999a: 29). Therefore the Brundtland report anticipates "a five to ten fold increase in world industrial output … before the population stabilises in the next century" (WCED in Ibid. 29), a goal which fully contradicts current estimates of global ecological carrying capacity. Such mainstream approaches believe that incremental changes to the political and economic status quo are appropriate and feasible to solve current social and ecological problems (World Bank in Bryant 1997: 5). This is in contrast to the three theoretical approaches presented in this investigation.

Ecological economics, with its inquiry into the thermodynamic foundations and costs of economic exchanges, marks itself as a paradigmatic challenge to the dominant neo-classical paradigm. This biophysically based approach to economics illustrates the "quasi-parasitic" relationship which the economy has to the ecosphere (Rees 1999a: 32). It reveals how many of the vital material flows, which the economy is dependent on, are invisible to conventional monetary analysis. By using the concept of entropy, entropic limitations become an apparent limiting factor on both the input and output side of the economic process. Since an expanding economy necessarily appropriates an increasing amount of the limited low-entropy energy/matter being formed in the ecosphere, and releases high-entropy wastes which must subsequently be absorbed, economic growth is ultimately constrained by the systemic limits of the flow of ecological goods and service (Ibid. 32). Given the current rates of resource consumption and the changes in the terrestrial environment caused by extraction and waste disposal activities, the material growth which some parts of the world have witnessed, and which many other parts of the world aspire to, are quite simply unsustainable. Therefore, ecological economics provides the basis for a critique of the theory of economic growth which underlies modern development.

While solar power, a dematerialised economy approach or improved control over pollution can help to alleviate some of the negative impacts of a high throughput economy, and will be important components in any future sustainable alternative, these strategies on their own cannot create the basis for continuing economic expansion. Rather than relying on the development of a

new viable technology that offers a questionable salvation to consumer society, humans need a way to live viably within the earth's ecosystems. In thermodynamic terms, in order for the economy to be sustainable, the amount of low-entropy energy/matter which the economy consumes must be less than its production in nature. The concept of "sustainability" which has appeared in international debates following the Brundtland report has been criticised for having normative undertones and lacking analytical rigour (O'Connor in Altvater 1998: 31). Therefore an alternative definition of ecological sustainability based on thermodynamics may be preferable. Ultimately, what is required to achieve sustainable ecological processes is a limit on the rate of throughput and therefore a limit on the rate of material production and consumption.

A purely ecological approach, however, also has its limitations, since human economic activity depends not only on physical and energetic factors but also on social institutions and organisation to direct and extend human energies in the transformation of natural resources. What must be added to the preceding ecological economics explanation therefore is the social dimensions of low-entropy energy appropriation - in other words the dimension of power.

The extension of the thermodynamic concept of open systems and dissipative structures to human social systems allows for the reformulation of social theory through energetics. The thermodynamic concept of open systems explains how all living systems maintain their internal order by sucking low-entropy energy from outside themselves, and discharging wastes generated by their own metabolism. In human social systems however, some of this low-entropy energy can be stored in enduring physical infrastructure and social organisation, and this tends to facilitate the continued or increased access to further sources of low-entropy energy. By considering the effect of uneven energy flows between extractive and productive economic social formations, the roots of environmental destruction and geographical uneven development can be characterised. This approach might be described as a spatialised (political) ecological economics.

Based on an historical study of extractive exports in the Brazilian Amazon, Bunker demonstrates how the varied modes of production and extraction in a world system of exchange are clearly distinguished by the way in which energy flows, the incorporation of energy into useful infrastructure, and the effects of energy flows on demographic distribution, social organisation, and various ecosystemic consequences. In the case of productive societies, the net flow of energy and matter permits a number of processes to take place which cannot arise in energy losing societies. These include: the increased substitution of non-human for human energies; increased scale, complexity and coordination of

human activities; an increased division of labour; and expanded specialised fields of information.[35] Such processes allow for increasingly complex systems of transport and communication, and stimulate technological and administrative innovation which ensure the continual flow of resources (Bunker 1985: 45). In contrast, the outflows of energy from extractive economies and the depletion of site-specific natural resources combine with the lack of consumption-production linkages and instability of internal demand to prevent the storage of energy into useful physical and social forms. The resulting local-level poverty produces an absence of political power, leading to an inability to slow down the rate of resource extraction or to raise the prices, leaving such energy-losing social formations increasingly vulnerable to domination by energy gaining social formations.

By relating exchange values to thermodynamics, the way in which market institutions organise the net transfer of energy and materials to industrial centres can be demonstrated. Energy appropriation is represented as reciprocal exchange through the creation of specific rates of exchange, which ultimately rest on human evaluations, and which guarantee a minimum net transfer of energy from one social sector to another. What this means in practice is that the majority of natural wealth gets transferred to industrialised countries, where it is transformed into industrial wealth, and finally appropriated by those with the necessary purchasing power on world markets (Altvater 1999: 9). Such findings suggest that an ecological perspective of unequal exchange would strengthen theories of underdevelopment and dependency and unequal exchange based on the under valuation of labour, and may also provide a more precise way of defining unequal exchange than previous explanations.

There is however some concern regarding the influence of neo-Marxist structuralism on the theory, which tends to produce overly deterministic interpretations and disregard the politically conscious subjects. This has led to the development of political ecology theories which demonstrate a more complex understanding of how power relations mediate human-environmental interactions. The last theory draws on a dialectical understanding of socio-spatial structures, where the organisation of space is seen not only as a social product, but also as *simultaneously* rebounding back to shape social relations. (Soja 1989: 57). Exploitation of individual regions is thus seen as existing not only through inter-regional relations of extraction and production, but also in a "multi-scalar hierarchy of exploitative relations that extends from the global to the local, from the world system to the individual factory and household units" (Ibid. 117). This comprises a much more complicated field of inquiry.

The centre-territory dialectic draws our attention to the generalised dynamics of various modes of organising power in both the physical and institutional

dimensions of spatial relations. The focus of analysis is on the dialectical struggle between two ideal forms of social organisation: a hierarchical centre that draws its wealth from distant places and less powerful social formations, and a territorial community that sustains itself locally and from within. This territorialist approach to political ecology points to the critical importance of protecting and re-building territorial forces as the essential foundation of social and ecological sustainability (M'Gonigle 1999: 18). It draws attention to the great variety of manifestations of centre power, and reflects the problematic character of many basic attributes of the modernist project including its faith in science and technology, its dependence on economic growth, and its destructive impact on traditional social and cultural systems (Ibid. 14). While still addressing the important character of capitalism and the market system, its recognition of a variety of centralist forces makes this perspective less economically deterministic than other Marxist-based analyses. Furthermore, the expanded focus of inquiry facilitates more creative responses to the precise circumstances of a specific context in order to empower and enable social action (Soja 1999: 71). This perspective thus reflects a distinctly cultural and spatial (political) ecological economics.

In the end, the path to sustainability appears to lie not so much in technology or markets, but rather in creating alternative forms of production and distribution, reinvigorating or protecting place-based, democratic and cooperative institutions, challenging the scientific foundations of the positivist perspective which underlies Western science and economics, and adopting or maintaining values which are consistent with sustainable ways of living. Looking more closely at the way that ecology, economics and politics interact, and the complex power relations underlying human-environmental interaction, is essential in order to gain deeper insights on how to approach the problem of ecological and social sustainability.

4. Operationalising Theoretical Constructions: From Abstract Theory to Strategic Level

The theory section has introduced three possible applications of a thermodynamically based ecological economics to an understanding of the problem of sustainability. Each privileges particular issues and areas, and contributes its own insights and understandings. The next section now turns to an examination of the ways in which these thermodynamically based understandings of (un)sustainability can be strategically applied in order to address the main elements of sustainability as defined for this project: ecological sustainability, social sustainability, and supportive socio-political institutions. These elements are quite obviously highly interconnected, and discussion of any one will necessarily take into consideration aspects of the other two. Each of these elements is also very complex and encompasses a whole array of possible

perspectives and arguments. The intention here is not to provide an overview of these varied perspectives, but rather to provide a particular alternative angle to each, based on a thermodynamic understanding, which can offer support and direction for a new emancipatory approach.

Reflecting on the problem of ecological sustainability, the first part begins by examining the relationship between society and nature, focusing on the concepts of time and space in order to expose a new understanding of this fundamental interaction. It is noted that many of today's environmental problems can be attributed to a difference in the development of ecological and economic systems. This has been facilitated by the well-established modern view that nature and society are completely distinct from one another. While mainstream economics continues to regard economics as a separate balanced system largely apart from nature, ecological economics exposes the absolute dependence of economic activity on nature. Attention to the thermodynamic basis of economic activity also points to the fact that all energy and material transformations take place within a particular space and time frame. An explicit focus on these spatial and temporal dimensions gives new access to an examination of the nature-society relationship, and points back to the significance of the transformation of materials and energy for economic theory.

Reflecting on the problem of social sustainability, the second part uses a thermodynamically based explanation to examine the North-South relationship. It is argued that in order to more fully understand the mechanisms which generate inequalities between North and South, the ecological conditions of human economies must be examined. The discussion begins by reviewing some of the basic assumptions behind export production, free trade and economic growth. The theory of ecologically unequal exchange is then applied to an analysis of North-South trade relations, based on the net flows of energy and materials. From this perspective, the physical transfers of resources from South to North, and their detrimental distributive implications, are clearly demonstrated. Finally, some examples of policy strategies at the national and international level, which incorporate an understanding of ecologically unequal exchange, are given.

Regarding the question of supportive socio-political institutions, a first step is to recognise the political deployment of space and, in so doing, uncover the hidden forms of power within existing socio-political institutions. The last section therefore begins by defining the need for a radically spatialised model of political economy in order to gain a critical understanding of the global restructuring which is currently underway. It then turns to take a closer look at the usefulness of a socio-spatial dialectic in order to recover a progressive articulation of place and empower a multitude of resistance. In particular, it

inquires into the insights which a territorialist political ecology approach can contribute towards a dialectical understanding of the relationship between local-global, state-civil society, and universality-particularity, in order to guide an emancipatory strategy which is able to overcome some of the common weaknesses of previous radical "localist" approaches.

4.1 Moving Beyond the Nature-Society Dichotomy

Many of the contradictions associated with conventional economic development can be understood by examining the fundamental beliefs and assumptions about the nature-society relationship. Whether society and nature are perceived as two separate or two highly integrated realms has important implications for the way problems are defined and delimited, as well as the scope and direction of analysis. The approach which has dominated Western-based natural and social sciences has been to think and act as if society is separate and independent from the environment. Humans have perceived themselves as masters over nature, able to adapt the environment to serve their needs. As a result, the interaction between social and ecological forces has been largely excluded from intellectual examination, and people have acted in ways that reinforce the society-nature dichotomy (Hartmann 1998: 344). Since the early days of industrialisation, economics has broken away from its traditional relations of premodern societies. The economy has been treated as an independent, self-regulating and self-sustaining system, lacking any representation of its dependence on the ecosphere. Driven by the logic of the market economy, economic relations and institution have been compelled to ever increasing production and consumption of goods and services, resulting in the current unsustainable ecological and social relations.

In the midst of rising environmental concern, recent theorising on the relationship between society and nature has been highly dynamic. Contemporary social theorists from a variety of perspectives are challenging the idea that nature and society are phenomenologically and scientifically distinct (Goldman and Schurmann 2000).[36] Mainstream economics, however, has remained largely inimical to this debate. This may seem surprising since the focus of economics on wealth-creation, efficiency in production, and the satisfaction of human wants would suggest an inescapability of a confrontation with the material conditions of economic activity (Redclift and Benton 1994: 3). Nevertheless, conventional economics continues to regard economic activity as largely distinct from natural necessity and the biophysical world.

In contrast, ecological thermodynamic science signals a paradigmatic shift away from the nature/society divide by revealing the absolute dependence of economic activity on nature. The view which emerges is that we live within nature rather than off of it. From this perspective, many of today's

environmental problems can be understood as an incompatibility in the development of ecological and economic systems. One way thermodynamics can help to expose this incompatibility is by making explicit the social and ecological aspects of space and time.

1. Matter, energy, space and time

In thermodynamic terms, economic production is understood as the transformation of material and energy, and like all such transformations they follow certain laws of nature with coordinates in physical space and time (O'Connor 1994). All physical processes leave the world changed in particular ways at particular locations. When attention is given to the thermodynamic basis of physical activity, it becomes impossible to abstract entirely from space and time, since all activity whether ecological or economic takes time, and space constitutes the frame of reference for all social and material activity (Altvater 1994: 78-80). This focus on space and time gives new access to an examination of the nature society relationship. From this perspective, problems can be understood to arise when the space and time of a society are not in sync with the space and time of nature. Ecological crises can therefore be seen as a collision between different temporal and spatial characteristics of economic and ecological systems[37] (Altvater 1994: 82). Both systems have developed over time, but have followed different organisational principles with respect to the basic factors of energy, matter, space and time (Ring 1997: 237).

The aspect of time that is of primary ecological significance is the irreversible character of material and energy transformations, as shown by the second law of thermodynamics. In nature, transformation processes are organised in such a way as to maintain a dynamic equilibrium between entropy intake and entropy discharge (Altvater 1993: 203). Moreover, many important processes in nature are characterised by extremely slow time rates. For example, soil and groundwater can take hundreds or thousands of years to regenerate. In addition, unlike historical linear time, time in the natural environment is characterised by rhythmic variation and synchronisation within an all-embracing, complex web of interconnections (Adam 1994: 95). Thus human time, resource time and ecological time differ drastically from one another. As Adam explains, linear sequences do take place in nature, but as part of a wider network of cycles as well as finely tuned and synchronised temporal relations and spatial patterns where ultimately everything connects to everything else (Ibid. 95). Thus the parts of an ecological system resonate with the whole, and the whole with the parts.

In contrast, the world of human practices differs significantly from the temporal and spatial characteristics of ecosystems. The fine balance of ecological interconnectedness and exchange is lost in the material world of modern

economics. Cars, steam engines, or nuclear power plants are governed not by the laws of entropy but by economic growth and development (Adam 1994: 95). Emphasis shifts from process to product, permitting economics to isolate itself from the other life processes and ecological interactions which it is dependent on. For the most part, economic agents are indifferent to the physical dimensions of material and energy transformations, as long as their enterprise remains viable (Altvater 1994: 86). This requires that a sufficient profit is made so that a new cycle of the transformation process can be set in motion. Where time is commodified, speed becomes an economic factor. The faster goods move through the economy, the higher the profits. When "time is money", space represents little more than the time and expense needed to cross it (Ibid. 77). In the effort to maximise profits and increase efficiency of production, time and space must be compressed and abstracted away from. Efforts must likewise turn to shaping physical space in order to compress the time of activity (Ibid. 77). Space comes to represent a series of obstacles which must be overcome in order to increase the speed of material transport; and speed is indeed increasing with modern transportation reducing travel time to a minimum, and modern communication technologies overcoming space in a matter of seconds. When time can be reduced to little or nothing, the meaning of space is also significantly reduced.

In addition, world markets have all but eliminated spatial distinctions (Altvater 1994). Resources can be used from any place in the world, just as products can be sold all around the world. The non-regenerational use of resources or destruction of natural habitats is of little concern to economic agents, as long as there are resources and habitats left to exploit somewhere else (Ring 1997: 242). In addition, the temporal range of economic calculations diverges sharply from resource times and waste disposal times. With modern technology, humans can impact ever greater spheres of nature, moving beyond the point where the consequences in space and time can be predicted or controlled. Paradoxically, the larger the potential impact the less control we seem to have over the consequences. Take for example the case of nuclear power. The planning horizon of nuclear power companies is perhaps at most several decade, while the half-life period of high level radioactive wastes is around 100,000 years (Altvater 1994: 86). Moreover, as Chernobyl demonstrated, nuclear disasters have the potential to impact expansive areas of the globe, and create an environmental hazard to be managed from generation to generation. Such "solutions" illustrate the extreme mismatch between ecological and economic time and space.

While the history of modern manufacture can be seen from the outset as one of ecological disruption, the global industrial system has taken these negative impacts from local to global proportions. Nevertheless, ecological devastation

has not become systematic due to industrialisation *per se*, but rather due to an inherent economic logic which tends towards an infinite exploitation of natural resources, and requires continuous growth to survive (Hayward 1995: 119). While capitalist economic systems have these tendencies at their very essence, it also applies to former socialist countries which appeared as low-growth economies, but which also aimed for high rates of accumulation. As Altvater points out, these countries were "both ecologically destructive *and* less successful in terms of market economics" (Altvater 1993: 204). In either case, social systems have been created where the spatial and temporal coordinates of the structures and norms are completely disconnected from the spatial and temporal coordinates in nature.

2. Quantitative flows versus qualitative changes

The relationship between ecological and economic systems can also be understood in terms of quantitative versus qualitative processes. As Altvater explains, modern growth economics is primarily a process of quantitative increase of values (Ibid. 183-225). Energy and matter are measured not in terms of changes in their quality, but rather through flows of money, expressed either explicitly with a price, or implicitly when provided at "no cost". Reducing transformation processes to their monetary value masks their natural spatial and temporal qualities. Furthermore, the possibility and necessity for growth of quantitative value, in terms of profits and accumulation, means that qualitative limitations must be transcended, whether that be by technological, social, economic, or political means (Altvater 1994: 88). It is this reduction of qualitative properties to a common monetary form which has made the spatial expansion of quantitative accumulation possible (Ibid. 87).

Nevertheless, ecological change in the real world is felt in terms of the qualitative changes which occur during processes of energy and matter transformation. While the quantity of energy remains constant in a closed system, regardless of transformation processes, qualitative changes or regroupments of energy and materials take place (Altvater 1993: 99). Entropy is the ecological measure of this qualitative process of material and energy transformation. Unlike monetary measures, it is non-circular and irreversible. The mismatch between the goal of quantitative accumulation and the qualitative realities of economic processes is readily observable. For example, within the economic rationality of quantitative accumulation, where all other things are equal, it makes no difference whether an output of 100 units or 1000 units achieves a certain profit (Ibid. 225). However from an ecological perspective, clearly 1000 units requires a much greater throughput of energy and materials and results in greater ecological disturbance. Furthermore, the economic ethic of maximum sales means the briefest possible use and cheapest possible construction (Adam 1994: 107). It follows that the qualitative conditions

associated with the production and consumption of commodities are kept out of view. For example, car manufacturers never publicise the vast quantities of materials and energy used in a car's production, or the amount of toxic emissions given off as wastes, or the immense amount of energy and materials which go into the construction and maintenance of highways. Regardless of any "green" tinge advertising may be given, the purpose is to create a need for consumption, not to motivate consideration about the qualitative effects of transformation processes. It becomes apparent that the economic attempt to internalise negative environmental effects can never compensate for the ways in which natural conditions are altered through production, consumption, and distribution processes (Altvater 1993: 186).

3. Transcending the divide

The illusion of an infinite process of quantitative accumulation and disregard for the qualitative irreversible changes in entropy and associated ecological disturbances is at the base of the conflictual relationship between economics and ecology. In an economy without spatial or temporal constraints, nature can be largely disregarded. However, since humans are themselves a part of nature, disregarding nature ultimately undermines our own existence. A very different picture emerges when economic systems are analysed from a thermodynamic rather than monetary perspective. Rather than indicating economic success, high rates of profit usually indicate a high throughput of materials and energy, and therefore high rates of entropy increase (Ibid. 202). When time is associated with energy rather than speed and profit, it becomes apparent that the faster something moves or functions, the higher its use of energy and materials tends to be (Adam 1994:104). Speed in this sense becomes a liability rather than something to be aspired to. When profit and speed are viewed in this way, reducing the time of activity loses its meaningfulness, and space is allowed to take on a significance of its own. Once the spatial and temporal qualities of economic processes are recognised, attention must then turn back to the explicit significance of the transformation of materials and energy for economic theory (Altvater 1993: 184). In the long run, human systems cannot progress and evolve without taking into consideration such fundamental laws and principles of nature. Incorporating an understanding of matter, energy, time and space is a basic theoretical necessity to move beyond the nature/society divide, and foster the rebalancing of social and ecological systems.

4.2 Ecological Distribution and a Southern Approach to Sustainability

A thermodynamically based analysis of energy and material flows in the development process reveals important insights into distributional issues between countries of the North and South. From a thermodynamic perspective, advanced economic development is completely reliant on the capture of high value energy, and is constrained by its availability. This is evident from the

understanding that all production is the transformation of energy and materials. In addition, a necessary condition for achieving sufficient profit is increasing productivity (Altvater 1993: 204). Apart from gains in efficiency, the only way in which productivity can be increased is by consuming greater quantities of matter and energy, and by replacing human labour with fossil energy and machinery (Altvater 2002: 9). The economies and social structures of the advanced industrialised countries, in particular, have evolved over the past century to take advantage of the opportunities which the exploitation of fossil fuels provided (Norgaard 1988). It follows however, from the law of entropy, that increases in productivity lead to an increase in entropy, since the natural direction for all energy and material transformations is towards an irreversible, qualitative deterioration of energy and materials. This is the conflictual relationship which has been described for ecological and economic systems.

It is important, however, to point out that this qualitative degradation of energy and materials or increase in entropy applies only within a closed system. If energy and materials can be introduced into the economic system from the surrounding world, or entropy discharged into an external system, then it is possible to increase productivity without jeopardising the ecological conditions within the system where the productivity increase occurs (Altvater 1993: 201-204). The external system may be represented in spatial terms, such as the exploitation of distant resources or shipping of toxic wastes abroad, or it may exist in temporal terms, as in the plundering of resources necessary for future generations, the underground storage of radioactive wastes, or irreversible changes in climate. Martinez-Alier uses the term “ecological distribution” to refer to the social, spatial and temporal asymmetries or inequalities in the use of natural resources or in the burdens of pollution (Martinez-Alier 1997: 233). However, in nationally focussed economic analyses, where the assumption is one of open systems, then increases in entropy do not necessarily apply. In fact, some countries exhibiting high productivity, such as Germany and Japan, may be ranked as some of the most ecologically sustainable (Pearce and Atkinson 1993: 103-108). This is possible since the physical dimensions related to the energy and material flows necessary for production are not reflected in conventional economic analyses. Tracing the flow of materials is essential in order to understand the differential costs to the various regions involved in the total process of production.

1. Material realities and economic fallacies

By considering where energy and materials are coming from at the global level, it can be clearly shown that the third world is specialised in the exploitation of natural resources. Using monetary-based statistics, the IMF reported in 1998 that primary commodities accounted for the largest share of developing countries’ export earnings, with 45% of developing countries having primary products

(fuel and non-fuel) as the main source of export earnings (IMF in Muradian & Martinez-Alier 2001: 287). In fact, unprocessed raw materials accounted for an estimated 75% of the 48 poorest countries exports in 1995 (OECD 1997 in Ibid.). Furthermore, around two-thirds of all primary commodity exports are consumed by developed countries. While the exporting sector does not constitute the bulk of economic activity in most Southern countries, it can nevertheless have large negative environmental and social impacts relative to its economic share since it relies primarily on the exploitation of natural resources (Muradian & Martinez-Alier 2001: 287)

Regardless, specialisation in the export of abundant raw materials and primary commodities by the South is seen as beneficial to their development, and is actively promoted by international institutions such as the World Bank and IMF. The basis of the dominant economic theory of trade is the "law of comparative advantage" formulated by Ricardo more than 200 years ago. According to this theory, trade leads to benefits to both sides of a trading arrangement, regardless of any absolute advantage a country may or may not have, as long as each country is trading a good which it can produce at a lower *relative* cost than other goods (Common 1995: 264-258). The core of the theory is the role of specialisation. A country is said to have a comparative advantage as long as the commodity which it "produces" requires locally abundant factors and little of scarce factors. It then trades this for goods that call for factors in the opposite proportions. It is therefore assumed that both importer and exporter countries can gain through trade, though it does not claim that gains are distributed equally. In addition, the staple theory of growth,[38] argues that the expansion of the resource-base exporting sector induces higher rates of growth of aggregate per capital income due to links with other sectors of the economy (Watkins in Muradian & Martinez-Alier 2001: 287). Free trade can even be argued to have a positive effect on the environment, since economic growth leads to higher tax revenues which governments can then spend on environmental protection measures and improving environmental quality (Bhagwati in Sustainable Europe Research Institute 2001). This line of reasoning is supported by the "environmental Kuznets curve" (EKC) which describes how the levels of certain pollutants declines with increasing per capita incomes.[39] Economists in support of these propositions therefore argue for a general positive link between free trade, growth, and environmental quality.

While it is true that trade triggers development, due to the global division of labour developed over hundreds of years, trade fosters a particular model of development. Clearly, not every comparative advantage promotes development in the same way. Countries endowed with agricultural, mineral, and energy resources have tended to remain extractive, while those countries specialising in industrial products have been able to acquire a competitive advantage (Altvater

1999: 9). Previous arguments put forward in theories of imperialism, dependency, and unequal exchange based on wage or productivity differentials, have all recognised primary material export as a defining characteristic of most forms of underdevelopment. However, the approach of ecological unequal exchange has extended these theories by adding a consideration of the large environmental impact of the specialisation in the exports of natural resources. The theory of ecological unequal exchange underlines, first of all, the fact that primary commodities from the South, which may take a very long time to regenerate, are traded for rapidly manufactured products or services from the North. Furthermore, it takes into consideration the many unaccounted and uncompensated environmental externalities of export production and their social impacts. These are the hidden costs which never make national accounts. These take into account the energy and materials required in the total process of production and consumption, right from extraction to disposal. In addition, it takes into consideration the differential capacity for energy-losing and energy-gaining societies to direct human and non-human energy, and conserve part of it in enduring infrastructure and useful social forms such as an increased division of labour or specialised fields of information or technological innovation. As Bunker's study demonstrates, all of these have a profound effect on the possibilities for long-term development. The point is however, as long as economic theory only investigates connections between countries in terms of commodity imports and exports, capital movement or financial flows, then the existing ecological asymmetries remain largely invisible. By thinking more in terms of net flows of energy and materials rather than national trade statistics, the material realities of North-South relations becomes much more explicit (Hornborg 1998: 173). When production is understood as being reliant on the extraction of high value energy from somewhere, and when the hidden costs of things subtracted from ecological systems and their social impacts are recognised, surplus production begins to reveal itself as the "economic conquest of space" (Altvater 1994: 88).

It is currently evident that many Southern countries which specialised in resource intensive sectors and primary exports are now confronted with long-term, dynamic disadvantages. This has been described as "the specialisation trap" (Røpke 1994). In economies based on non-processed products, there are really only two possibilities for increasing export earnings. The first is to get an agreement among all exporters to maintain high prices and control supply, which is difficult to do and seldom successful for a variety of political and economic reasons. The other possibility is to increase supply, but this eventually causes a downward pressure on prices and deterioration in terms of trade (Muradian & Martinez-Alier 2001: 287). With a fall in prices, countries must then sell even greater quantities just to maintain the same level of revenues. Tariff escalation, that is rising import duties with the level of processing of the

goods purchased, helps to maintain this specialisation trap. So do huge debt loads which force many Southern countries to increase exports in order to service their debts, adding further to the fall of prices along with increasing environmental damage and resource depletion. This tendency is confirmed by statistics over the last decades which show that the prices of primary resources have dropped substantially (Ibid. 287). Moreover, in contrast to the staple theory of growth empirical evidence shows that the growth of primary exports exhibits little or no external impact on the non-export sector, which constitutes the bulk of economies in most developing countries. Altvater's study of the Brazilian Amazon, for example, concluded that projects based on resource extraction oriented towards a world market, mostly fail to build a linkage to the local economies (Altvater in Sustainable Europe Research Institute 2001). Rather than promoting long-term development, the export of primary commodities was shown to cause an increase of entropy in the region and restrict future development possibilities. Therefore strategies to develop the export-oriented primary sector may lead to "illusory" growth in the short term, but unsustainable development in the long term.

The neo-classical theory of free trade is based on a fundamental assumption that prices in the international trading system always reflect the full costs of production, that is, that no externalities occur. However, as has been shown, unrecognised and uncompensated externalities are an inherent part of the world trading system. When countries export commodities at prices which do not take into account the negative local externalities caused by the extraction of resources or the production of the commodities, then a shifting of costs occurs, spatially and/or temporally. Based on this understanding, some ecological economists argue that free trade is an incentive for producers to maximise the externalisation of environmental costs, and lower environmental and social standards, thereby leading to a "race to the bottom" (Ayres 1996 in Sustainable Europe Research Institute 2001). Others however point out the international specialisation occurring where poor countries are not only specialising in primary exports, but are also attracting "dirty" and material intensive production, while richer countries specialise in clean and material extensive production (Muradian & Martinez-Alier 2001: 286). If this is correct, then free trade is not so much promoting a general deterioration of environmental standards but rather, promoting environmental improvement and economic growth in the North, and environmental deterioration and economic stagnation in the South. This would then also provide an alternative explanation to the Environmental Kuznets Curve which argues that economic growth leads to a better environmental quality. On the contrary, it seems that the environmental costs of Northern material consumption are being disproportionately suffered by Southern exporting countries.

It is however of some significance to point out that the World Bank reported in 1998 that for the seven most polluting economic sectors, developing countries tended *not* to specialise in heavy polluting industries. Based on monetary statistics, poor countries were shown to be net importers of environmentally intensive products, as well as increasingly net exporters of products with big environmental rucksacks (World Bank in Ibid. 290). Here it is important to note the difference that units make, since if physical units in weight are used rather than monetary units, then wealthy European countries rather than poorer countries can be clearly shown to be net importers in these polluting sectors (Ibid. 290). This gives a concrete illustration of how monetary units obscure the ecological transfers from North to South.[40] Furthermore, when weight units are converted into physical measures such as invested energy or hectares (as in the ecological footprint), then imports of environmentally intensive goods from the South can be shown to be of much greater significance. Therefore a thermodynamic analysis provides support for the assertion that Northern countries maintain a high level of production and consumption and improve their local environmental standards, at the expense of the South.

There is, however, still the problem that in a world of limited resources and sinks, it is not possible for all societies to acquire the level of energy and materials necessary for a modern consumer lifestyle. As ecological footprinting reveals, if everyone were to live like North Americans, we would require three planets to produce the resources, absorb the wastes, and otherwise maintain life-support (Wackernagel and Rees 1996: 15). What solutions are there to this predicament?

2. Carbon commodification – a market-based solution

The current approach to solving the problem of ecological limits, is first to identify the limits, and then decide who is entitled to the further exploitation of nature. From Bunker's perspective, this decision will be dominated by the regulatory sectors of the core zone which have the power to control the energy forms and flows in the world. This does indeed seem to be the case in the "global ecology" arena where, as Sachs (1995) points out, diplomats with different levels of power and persuasion formulate environmental concerns in such a way as to maximise their own country's share. The results of these power differentials have attracted accusations that the dominant political and scientific discourse around environmental issues is being constructed so as to support a Northern agenda at the expense of the South.

Taking a look at the much publicised issue of climate change, the solutions proposed in the Kyoto Protocol are based around the idea of tradable carbon credits, with current national emission levels suggested as a baseline for credit distribution. The use of economic instruments is seen to reward individuals and

companies who find cost-effective ways to reduce their emissions, while at the same time, allowing the largest reduction of emissions possible for a given amount of investment. It is also seen as a way to transfer funds from North to South that can be used to clean up environmental problems there, through the purchase of emissions credits or participation in the "clean development mechanism". These are convincing arguments within the logic of economics, and such free-market solutions are finding support among many advocates.

However critics argue that the Kyoto protocol is essentially a corporate-friendly environmental trade treaty which facilitates the appropriation of the global commons and the atmosphere by private and public corporations, at the expense of equity between North and South, and even to the detriment of the climate itself (http://www.risingtide.ml/cop65/principles.html). Efficiency and cost-effectiveness are upheld as the dominant virtues, while such questions as levels of consumption or which actors are responsible for the most historical or current emissions are downplayed. Carbon commodification and joint implementation[41] are seen as mechanisms for establishing an “eco-colonial” division of the world's resources, where industrialised countries are allowed to maintain their high consumption by paying the South to keep their emissions down through investment in forests, energy efficiency projects and so on. Also when the targets recommended by the UN International Panel on Climate change, for a 60% cut in emissions as soon as possible, and further reductions of 90% to avoid global climate catastrophe and reverse the effects of climate change, are compared with the reduction targets of around 5.2% discussed in Kyoto, it appears that even the original mandate of stabilising atmospheric greenhouse gas concentrations has been forgotten (Sokon, Najam and Huq 2002).

An alternative policy framework known as "contraction and convergence" has been gaining support in recent months, and is said to meet the US demands for developing country participation, the South's concerns for equity, the private sectors needs for flexibility and efficiency, and the EU and NGO calls for a framework with environmental integrity (Simms 2001). It requires an agreement for a global contraction of emissions from human sources of 60-80% within a specified time frame. International implementation is arranged so that entitlements to emit are predistributed in a pattern of international convergence so that shares become equal per capita globally. It also allows for a trading mechanism in order to "smooth the transition" and allow resources and technology to flow to the South (Ibid.). While it does not challenge the globalist scientific and economic constructions of the climate change issue, it could be seen as a first step towards a more meaningful cluster of agreements.

The problem however is that the global climate change issue has proven to be such fertile ground for advocates of market mechanisms who, as Lutes

describes, “are more interested in maintaining profits and keeping the world safe for corporate capitalism, than in creating a world in which society and nature can reconcile their differences in a mutually supportive manner” (Lutes 998: 170). With the reality of policy makers’ defined by economics, those with monetary wealth in the North can be expected to do all they can to ensure that their purchasing power can be used to secure access to sources and sinks necessary for continued production and consumption. Also, with the impacts of Northern activities over the exploitation of resources in the South going largely unnoticed, the South is left to make disproportionate sacrifices in order to stay within global ecosystem limits. In order to counter this tendency, alternative constructions of the sustainability issue need to be promoted along with strategies which can lead to progressive change.

3. Material flows perspective and ecological debt

When the problem of sustainability is viewed from the perspective of material flows and ecologically unequal exchange, a very different set of answers arise. From this perspective, the main environmental concerns are related not so much to resource scarcity as to the ecological impact of resource extraction, processing and use of resources in the economic process (Sustainable Europe Research Institute 2001). When this is recognised, it becomes vital to assess the material flows associated with production of export commodities, and analyse the ecological and social impacts of extraction and uneven energy flows. Material flow accounting has been developed to calculate the material bases of various human activities[42] (Wuppertal Institute in Ibid.) Material inputs include not only those materials contained directly within a commodity, but also those materials which are not physically present, but which are necessary for extraction/production, use, recycling and disposal[43]. Accounting for these hidden flows or “ecological rucksacks” would make many of the negative consequences associated with export production and their impacts on local populations clearer. Other physical indicators used to judge the overall impact of the economy on the environment include environmental space and ecological footprint. Both define how large of an area of productive land is needed to act as both source and sink in order to sustain a given population indefinitely at its current standard of living and with current technologies[44] (Rees &Wackernagel 1996; Sachs et al. 1998).

It is however impossible to measure all of the energy transformation processes involved in human activities, since we are unable to measure all of the complex energy exchanges in the effected ecosystems, nor are we even aware of many transformations. Also, while Bunker demonstrated the necessity of high energy flows for such things as complex social organisation and advanced technology, the energy values of these can not be directly measured. Still, it is possible to analyse the different potentials for social organisation, infrastructural, and economic development in societies which import materials and energy from

outside and societies which export them, based on the logic of the relations between them and the laws of thermodynamics (Bunker 1985: 244). This then allows for useful comparisons to be made between the results of different energy flow-throughs in different societies.

There is also increasing reference to the "ecological debt" which the advanced industrialised countries have to the developing South. While the term is currently mainly used with reference to the historic and current levels of carbon dioxide emissions, a thermodynamic perspective makes clear the multiple negative impacts associated with the extraction of resources and specialisation in the export of primary commodities and manufacture of material or pollution intensive products, all of which go to make up this ecological debt. The ecological debt can also be traced back to the stripping of resources and loss of life associated with centuries of colonisation. Furthermore, the ecological debt continues to accelerate today, with increased pressure for exports from structural adjustment programs, intellectual appropriation of ancestral knowledge, degradation of the best soils for cash crops, and the inequitable manner in which climate change is confronted through joint implementation programs (http://www.s-jc.net/ecologicalDebt.htm).

Recognition of the ecological debt could have far ranging political and economic consequences, and there are currently several international campaigns which are applying the concept of ecological debt towards progressive ends.[45] It is, for a start, being used to show the responsibility and obligation of industrialised countries of the North to stop damage to the biosphere and countries of the world through a reduction of emissions proportional to this debt, and through assisting other countries in dealing with the effect of climate change who are not responsible historically for its causes. In addition, recognition of the ecological debt is making evident the multiple inequalities of the present world market system, and promoting resistance to economic globalisation. More importantly the ecological debt makes the external debt of third world countries illegitimate, since the external debt appears as minimal in comparison with the ecological debt of the industrialised countries, measured in terms of its devastating social, cultural and environmental impacts.[46] Also with the external debt being used as political pressure for the over-exploitation of natural resources, it can be concluded that both the external debt and the ecological debt are principal causes of unsustainability and global ecological destruction, and therefore in order to deal with the current ecological crisis, both debts must be redressed.

Serious redressing of the ecological debt would need to start with international institutions canceling the external debt and the associated structural adjustment programs in affected countries. Pressure could then be exerted for the restoration

of areas in the South which have suffered from the extraction of natural resources and export of monocultures, so that local and national communities could recover their capacity to be self sustaining. Furthermore, in order to stop increasing the ecological debt, free trade policies would need to be replaced by policies favouring nationally focused and autonomous economic development, which prioritise the needs of the national population and develops in harmony with the environment. Such outcomes would obviously require a great deal of concerted effort from people and governments in the South, as well as from people and organisations acting in solidarity in the North, in order to successfully challenge international power differentials.[47] However, the recognition of the distributive implications of the continuing appropriation of materials and energy could be expected to give new life to these redistribute struggles. It is perhaps even imaginable that it may be recognised that some goods are simply more important than others, and that nothing can compensate or substitute for the minimum amount of energy intake necessary for human life.[48] While such policies are not likely to be adopted in the next rounds of economic or environmental summits, increasing awareness and continuing pressure is necessary to make these arguments into conscious and more widely acknowledged political issues.

This alternative, thermodynamically based understanding of ecologically unequal exchange and ecological debt could provide the basis for a Southern approach to sustainability. It demonstrates how the reliance on the extraction of primary goods as a base for development is not only economically unsound, but also has a negative impact on social development, political stability, and ecological integrity in extracting areas. The transfer of natural resources from North to South and exploitation of whole ecosystems, on the one hand, and exploitation of labour and unequal distribution of monetary wealth, on the other, must therefore be considered as separate but complementary phenomena which affect the potential for long-term regional development and socio-ecological sustainability.

4.3 Challenging the Power and Control of Spatial Structuring: A Territorialist Approach for Change

In the territorialist political ecology approach, a dialectical understanding of the spatiality of social life is seen to offer a radical spatial redirection for political ecology. Combined with an analysis of energy flows through institutional and geographical space, it provides new insights into the organisation of space, the relationship between social and spatial structures, and the cultural and/or ideological content of socially created space. The question of interest now is, how useful is this expanded spatial knowledge for providing a critical understanding of the contemporary world and for guiding an emancipatory strategy?

1. Institutional roots of contemporary restructuring

To begin with, an explicitly spatial perspective appears to be particularly relevant for understanding the intensive societal restructuring which has been occurring over the last three decades. This restructuring is often referred to as "post-fordism" or the "fourth modernisation" of capitalism.[49] Among the trends characterising it are: an increasing centralisation and concentration of capital ownership; more integration of diversified activities, resulting in parallel branches, subsidiaries, subcontracting firms and specialised public and private services; pronounced internationalisation of capital which is able to explore and exploit markets all over the world with fewer territorial constraints; global restructuring of industrial production and changing international division of labour; overall decrease in the relative proportion of manufacturing employment resulting in a changing regional division of labour; more pronounced polarisation between high pay/high skill and low pay/low skills occupations and increasingly specialised residential segregation based on occupation, race, ethnicity, immigrant status, income and lifestyle (Soja 1989: 184-187). These and other restructuring processes contain an enigmatic mix of paradoxes and contradictions which defy simple categorical generalisations and conventional tools of understanding. While there is general agreement that this restructuring was sparked by a series of crises, such as the end to the post World War Two economic boom and the sixty's rebellions, there is less agreement as to the cause of them. One way to understand the roots of these crises is by examining the institutional structures which have shaped and sustained the post World War two economic systems. These include not only the established international division of labour, distribution of political and economic power, and patterns of uneven regional development, but also developed forms of exploitation of women, minorities, and the natural environment, the spatial morphology, industrialisation, and financial functioning of metropolitan areas, and the design and infrastructure of the built environment, and collective consumption (Ibid. 169). In this way, the complex interaction between the production of human geographies and the constitution of social relations and practices can be opened up to theoretical and political interpretation. A spatialised model of radical political culture appropriate to this task has been defined as "an 'aesthetic' of 'cognitive mapping', an ability to see in the cultural logic and forms of post-modernism an instrumental cartography of power and social control: in other words a more acute way of seeing how space hides consequences from us" (Jameson in Ibid. 62). This, Soja asserts, is the key to making political and theoretical sense of the contemporary world.

2. Social movements and a re-visioned spatiality

In this light, urban social movements can be essentially understood as the political response to the structural contradictions arising from this increasingly

global spatial planning process, by those subordinated and exploited by it (Castells in Peet and Watts 1993: 244). Social movements include a multiplicity of groups from squatter movements and indigenous associations to gay rights, women's rights, anti-globalisation, anti-racist, and environmental movements. While Marxist theory identifies class relations as the key to the structure of domination and forms of resistance, the multitude of culturally constructed identities and collective struggles present in "new" social movements takes them beyond the bounds of class struggle and its associated binary categories, such as capital versus labour or bourgeoisie versus proletariat[50] (Laclau in Ibid. 244). Nevertheless, there appears to be a general tendency within these movements to follow a similar bipolar logic, where differences in power are ordered around a dominant and subordinate social category, such as white and black, man and woman, majority and minority, or heterosexual and homosexual (Soja and Hooper 1993: 185). These discrete binary categories tend to create a kind of competitive exclusivity between various radical movements, thus limiting the possibilities for strategic alliances. Dialogues between groups do of course occur, but often a group is reluctant to enter an alliance unless it is under their own terms and strategic guidance. This results in parallel rather than intersecting channels of radical political consciousness (Ibid. 186-187). As such, binarism can be seen to constrain the development of a radical alternative, and are moreover too restrictive to understand contemporary relations of power. This does not call for a complete dismissal of binary relations, since they continue to describe important features of social life, history, and politics. However, a recognition of their strengths and limitations is essential, in order to move away from a restrictive politics which searches for "the singular transformation to precede and guide all others" towards a cultural politics which can empower a multiplicity of resistances (Ibid. 187).

It is here that an appreciation of the essentially dialectical character of social and spatial relations provides a fresh understanding which goes beyond the simple structure of closed dualism. An expanded understanding of the relations between space, knowledge, and power is stimulating, what has been called, a new cultural politics of space, class, race, and gender (Soja 1999). Moving beyond a politics that revolves primarily around a single channel of unequal power relations, the recombinant cultural politics searches for a more comprehensive and less exclusive terrain for political action. Soja suggests: "What unites all these sites is a shared consciousness of the power and control embedded in the spatiality of human life, how all forms of human oppression and degradation are at least partially sustained by and through the production of specific geographies…" (Ibid. 70). Such a re-visioned spatiality allows for the empowerment of multiple sites of struggle, and the formation of strategic coalitions among all those who are marginalised by asymmetric power relations, whatever their source. Where a multiplicity of groups are empowered, this

facilitates a kind of "guerrilla warfare" where a wide range of resources, capabilities and communities can be drawn upon. The down side however is that such a multiplicity of resistances may also lead to a politically debilitating fragmentation, as well as have difficulty distinguishing between important and irrelevant struggles (Keith and Pile 1993). Furthermore, resistance is not always progressive, as the rise of extreme right wing movements across Europe and the US are evidence of, and combining certain movements together can be counter-productive. A key to resolving such dilemmas may lie in using resistance as a first step towards imagining and creating alternative future. This would entail "a transition from collective actions based on resistance identities to struggles based on project identities" (Castells in Mohan & Stokke 2000: 258).

Political ecology can assist in building such project identities by specifying shared political aims and interests that can bind together divergent actors in order to build alternatives and challenge political and economic interests supportive of the status quo. Here, a territorialist political ecology approach may be of particular relevance. Its dialectical analysis of energy flows through space is able to provide a more concrete understanding of the significance of spatial structures and their affects. With its expanded spatial understanding, and vision to transform both social and spatial structures through a rebalancing of centre and territorial relations, it provides a base point for envisioning a multitude of creative possibilities. At the same time, its understanding provides some broad guidelines which can be used to critically assess activities as part of an attempt to move towards an alternative political economy based on social and ecological sustainability. By drawing on ecological economics and the entropy-generating nature of all material production, it is able to build on a general social problem, and provide an important rallying point for binding divergent movements and organisations. As Altvater notes, "…the natural environment cannot be ascribed to vertically divided class interests or horizontally juxta-posed interests of particular groups. They are present in every individual and concern all (vertical) classes and (horizontal) groups equally if one disregards for a minute class-specific avenues of [temporarily] escaping the effects of environmental degradation" (Altvater 1998: 38). In contrast to approaches such as core-periphery analysis, where the periphery is marginalised in its very terminology, a territorialist perspective provides a peripheral position which can be used as a site of opportunity. Territory, defined as a non-hierarchical community living in "place", is not a position one strives to transcend in order to move into the centre. Rather it is a place one chooses as a site of "radical openness and possibility" where new alternatives can be imagined and practised (hooks in Soja and Hooper 1993). At the same time, the aim is not to assert the dominance of territory over centre, in a rigidly maintained bipolar order, but rather to examine the mix of tensions and contradiction that exists in any particular

context, and then look at new ways of responding in order to rebalance the relations.

3. Scale and politics: developing a global sense of place

The issue of scale is of particular concern regarding strategies for resistance and alternatives to globalisation. The recent trend within radical development studies has been to look towards civil society, participation, and ordinary people as important elements to an alternative development vision (Peet and Watts 1993). In contrast to more familiar bureaucratic, top-down approaches to development, many alternative strategies are seen to begin locally. This move towards the local appears to be a promising tendency, offering the possibility of empowering multiple struggles and identities, as well as putting into practice a broad range of innovative alternatives. At the same time however, there are a number of important weaknesses to a localist approach which need to be recognised. For a start, the focus on the local can be used for different purposes by very different ideological interests. For example the move towards local participation and empowerment has occurred within both post-Marxists and neo-liberal camps, but with almost opposite intentions. The neo-liberal version has a market-driven agenda of decentralisation, which focuses on the local as a means to break the power of central ministries, improve the efficiency of service delivery, and increase revenue generation (Mohan and Stokke 2000). Local participation is limited to including certain target groups in this top-down strategy, and thus, empowerment of marginalised groups is seen as achievable within the existing social order. In contrast, the post-Marxist version sees empowerment as a matter of collective mobilisation of marginalised groups against the disempowering activities of both the state and the market (Friedman; Castells in Ibid. 248). The focus is on local political actors, with particular attention to new social movements. It is however important for progressive forces to be aware of the opposing political interests in “the local” in order to avoid indirectly supporting neo-liberal strategies.

Nevertheless, even within radical uses of “the local”, there are a number of shortcomings (Mohan and Stokke 2000). One is the tendency to essentialise and romanticise the local, for example, by regarding it as a largely harmonious community undisturbed by conflicts of interests and power struggles. This view downplays local inequalities, and conceals powerful interests which may exist within the community. There is also the tendency to view the local in isolation of broader economic and political structures, with the result that the effects of national and transnational economic and political forces on the local are insufficiently examined. This critique also applies to social movements when they are conceptualised as autonomous sites of resistance and empowerment, apart from broader material and political processes. Finally, there is often a binary opposition set up between the state and civil society, where civil society

is regarded as a site of resistance to both the state and the market. The effect is that the multiplicity of links between actors within the state and civil society get neglected, and any potential positive role which the state can play, or indeed may be required to play, in order to assist beneficial developments is insufficiently acknowledged. In light of these concerns, it is essential to develop a political understanding of the local which can overcome these weaknesses.

Rather than conceptualising the local as discrete homogenous communities or sites of grassroots mobilisation and resistance, the local needs to be contextualised in order to develop a "global sense of place" (Mohan & Stokke 2000: 260). Here a territorialist political ecology approach can provide some important understandings towards accomplishing this. The key insight is that, while a territorialist approach implies the building of a territorial community which sustains itself within the limits of the local environment, the concept of territory goes far beyond the geographical concept of local. This is due to the combination of a dialectical understanding of place, as a complex interplay of geographical and institutional spatial relations, and an analysis of energy flows through these spaces. The flows of energy and resources necessary to maintain material production on the one hand, and centralist forms of social organisation on the other, are analysable at the local level, but these flows evidently extend far beyond any given locality. By extending the analysis of physical flows, one can see the relation between the direction of energy flows and the direction in which wealth, culture, authority, and power flow. Attention to these colonising lines of material supply necessarily brings in broader questions of social, economic, political, and cultural relations.

Within the local arena itself, attention to the dialectical tendencies of centre and territory reveals the complex mix of relations existing at the local level. There is no danger of reducing community dynamics to a simple either/or dichotomy of harmonious territorial relations or exploitative centralist relations. Material inequalities within localities are revealed, from a physical perspective, by inquiring into the internal use and distribution of resources. Power differentials are uncovered, from an institutional perspective, by examining how equitable and participatory processes of economic production and political decision making are, and how stratified its internal production relations are (M'Gonigle 2000). This allows a focus on the local while avoiding the problem of romanticising it. At the same time, since centre and territory are tendencies which exist in all forms of social organisation and at all scales, individual places must be seen as nested in a multi-scalar hierarchy of relations that extend from the global to the local. With globalisation causing societal restructuring at all scales, the driving force behind collective action is becoming global. This requires careful consideration of the complex linkages between scale and politics.

A territorialist perspective also has important implications for an expanded understanding of the state-civil society interaction. Rather than viewing the state and civil society as two separate spheres, a dialectical understanding of centre and territory draws attention to the dialectical relationship existing between the state and civil society. This is revealed in its call for both the reform of centralist institutions in order to support and protect rather than erode territorial values, and its emphasis on reinvigorating territorial forces in order to counterbalance destructive centralist tendencies. Attention to the dialectical relationship between centralist and territorial forces opens alternative strategies to a wider range of possibilities, from examining market forces, state regulation, and various levels of administration, to envisioning forms of co-operative alternatives and community decentralisation (M'Gonigle 2000: 16). Once again, this is a challenge applicable to all levels.

4. Relating the universal and particular

Discussion of the need for attention to dynamics at all scales leads to the question as to whether a territorialist approach could be generalised to all regions of the world, despite great differences in current situations, problems, regional histories, social forces, and cultural and social values. A look at social movements, for example, reveals that many movements in the North revolve around identity politics, whereas movements in the South are dominated by livelihood struggles. In regions where questions of poverty and deprivation dominate, actors may not have the same economic freedom to take into consideration ecological factors. Then again, the conception of the environment is itself culturally specific, and has a great bearing on how relations between the environment and society evolve. Even conceptions of justice and sustainability vary with place and time, not to mention from person to person. Therefore, it has been pointed out that the use of a single framework, without modification for regional differences, facilitates control from a single centre of analysis, disqualifies the majority of people, facilitates the domination of technocrats and experts, and encourages centralisation (Norgaard 1994a: 102). The question therefore becomes whether a territorialist approach can provide the theoretical foundations of a radical spatial praxis without "consuming the autonomy of the particular" (Peet and Watts 1993: 249).

There appears to be a number of reasons which suggest that this is possible. To start with, a territorialist approach to understanding space involves a full contextualisation of place, examining not only the flows of energy, commodities, information, wealth, and power, but also the related economic, social, cultural, and political relations. Also, while an understanding of flows extends beyond a particular locality, it also extends back into the past. For example, using energy analysis, technology, information, infrastructure, and

complex forms of social organisation can all be traced back to the steady flows of energy which have been required to develop and maintain them. At the same time, the realisation that the dynamics of space are constantly evolving and being intersected by diverse axes of power, brings an awareness of the limitations of our ability to understand spatiality. As Soja puts it: “A thousand historians could never hope to produce a complete biography of your life. So too is it impossible for a thousand geographers to make total theoretical and practical sense of a lived space” (Soja 1999: 71). This realisation automatically points to the necessity for a multiplicity of approaches to knowledge as a prerequisite to democracy and local control.

The overall strategy for change, envisioned within a territorialist perspective, entails a balancing of the tensions between centre and territory relations, in order to move towards a more ecologically and socially sustainable order. This general guide line however does not present itself as a unilateral recipe which forces groups to leave behind particular affiliations, feelings, commitments, or desires. On the contrary, the starting point for a territorialist critique is the rejection of universal truths, in particular the positivist perspective underlying neo-classical economics and Western science, and exposure of their unspoken social, cultural, and political biases. Such a critique highlights the point that all human understandings are mediated by social and cultural practices, assumptions and belief systems. Paradoxically, this also suggests that until the limits of positivist arguments are recognised in modern societies, they will need to continue to play a role there (Norgaard 1994a: 102). At the same time, it is important to draw attention to the ways in which the production of these universal models disguise or eliminate certain perspectives, issues, and questions. As Norgaard remarks, “Hopefully the conscious use of logical positivist arguments will also incorporate warnings of its dangers” (Ibid. 102). An awareness of the cultural nature of conventional modern economics and science leads to a recognition of a wide range of alternative methods and ways of understanding, allowing new and innovative ideas to be uncovered and put into wider circulation. This can then create a network of ideas, each with their lessons to teach, and problems to avoid, which can be explored and applied to new contexts where deemed appropriate, useful, and desirable. This does not entail a romanticising of non-western or precapitalist knowledge, but rather presents an important opportunity for the exchange of information, ideas, and understandings (Peet and Watts 1993).

Nevertheless, the whole idea of a transition towards more socially sustainable relations and practices suggests that a certain definition of social justice can be agreed upon. However, as Harvey points out, social justice is a “heterogeneous set of concepts” and varies in meaning depending on the standpoint of the person or group defining it (Harvey 1993). Therefore the struggle to have a

particular definition of social justice recognised as legitimate must be seen as a broader struggle between conflicting groups in any society. However, Harvey argues that the universality condition cannot be avoided, and that attempting to do so only hides rather than eliminates the objectionable conditions in question. At the same time, it requires sensitivity to the relationship between universality and particularity. He goes on to clarify:

> "…[U]niversality must be construed in dialectical relation with particularity. Each defines the other in such a way as to make the universality criterion always open to negotiation through the particularities of difference. The task of a progressive politics is to find [a] powerful, dynamic and persuasive way of relating the universal and particular in the drive to define social justice from the standpoint of the oppressed" (Harvey 1993: 62).

By offering an understanding and practice which overcome binary oppositions of local and global, state and civil society, and universal and particular, a territorialist political ecology approach appears to provide the contours of an emancipatory strategy of increasing relevance. Its attention to spatial relations, dialectical analysis, and physical flows allows it to recognise pattern and order in the dynamic tendencies and ever evolving arrangements of social and spatial structures, while remaining aware and open to the many unique and unexplainable aspects of space and place.

5. Conclusion

> "While some call the post-cold war period 'the end of history'[51] others sense we may be living at its beginning"
>
> James O'Connor 1994: vii

It is argued by some that the collapse of the Soviet Union signaled the "triumph" of capitalism, and the emergence of a universally shared truth of the best way to organise society. Its proponents announce that the only rational path to development is through economic growth, particularly rising productivity and increasing incorporation into global markets. International monetary and trade organisation, along with leading governments and corporations, push forward towards ever more globalisation and free trade, and more deregulation of economic and financial controls. Demands for neo-liberal economic reforms are being made almost everywhere, calling for privatisation of public sector enterprises, and reduction of fiscal constraints and public debt, most notably through cuts in social spending and imposition of structural adjustment programs. These are the dominant trends characterising the world political economy today, and they are backed by the most powerful states, institutions

and corporations. In such a light, it may seem little more than wishful thinking to speak of alternative understandings and strategies for development.

At the same time, there is a sense that we are living in an extraordinary time, where the very foundations of such economic and political practices are being deeply questioned. For a growing number, it is becoming impossible to remain oblivious to the many signs and warnings that something is wrong. The UN development program describes the current gaps between the world's richest and the world's poorest as "grotesque" and "historically unprecedented" (UNDP in Simms 2001). The downside of the wonders of technology are revealing themselves from pesticide resistance and nuclear disasters to increased incidents of cancer and climate change. The human and economic costs of global warming are rising dramatically, with a four fold increase in the number of climate-related disasters occurring in the 1990's compared to the 1960's (Ibid.). In Bangladesh alone, there is fear that climate change may create 20 million new refugees. In addition, the US economy is deflating, and following the crash of the "Asian tiger" economies, financial crises ripple outward with alarming frequency.

Signs of social unrest can be found almost everywhere. Meetings of the international monetary, trade and environmental organisation, which in the past created little or no protest are now drawing the attention of hundreds of thousands of global justice activist. From Seattle and Washington to Genoa, Prague, Quebec, and dozens of other places, neo-liberalism is under forceful attack. Some observers are drawing comparisons to the anti-war and anti-nuclear protests of the 60's and 70's, and to the 1968 Parisian "summer barricades". The unifying elements on this occasion are the power of corporations and interests of capital which are seen to sustain social injustices, destroy cultures, and exploit the environment, all in the quest for growth and profit. For some, these struggles have been going on for many decades (and even centuries), but now their protests are being joined by voices world wide to express their disillusionment and frustration with the current economic order. While many government and corporate leaders have been forced to publicly acknowledge the grievances of protesters, they continue to assert that global free trade and economic growth are not the villains, but rather that they are an important part of the solution required to create jobs, improve the environment, provide poor countries with the chance to join the "winners' circle", and create the conditions in which democracy and respect for human rights may flourish. Despite such claims, the majority of right leaning governments which have been governing the world over the last two decades, have shown themselves incapable of steering capitalist development in ways that improve the conditions of life for the majority and the environment. However, even with widespread dissatisfaction over neo-liberal policies, efforts to challenge them have had little success. Gare argues: "[Neo-classical]

economics has become the ultimate reference point for the justification of everything, and as such, transcends all evaluation" (Gare 2001).

By contrast, this paper has tried to demonstrate the potential which ecological economics has to challenge neo-classical economics as the basic discourse for defining reality. A thermodynamic understanding of ecological economics was shown to directly challenge the basic assumptions of conventional economic theories of growth by pointing to the physical limits of all growth, and more profoundly to the entropic nature of all economic activity. Living within these limits is now the major challenge facing high-throughput growth societies. With environmental systems already showing signs of stress, attempts to maintain the existing structure of economic growth can only be expected to deepen the current ecological crisis. Ecological limits therefore turn into social limits and finally into barriers to the dominant economic rationality (Altvater 1993).

A thermodynamic understanding was also used to expose a new angle to the nature/society relationship. By making the social and ecological aspects of space and time explicit, it clearly illustrated how ecological and modern economic systems have followed different organisational principles with respect to the basic factors of energy, matter, space and time. With modern economics completely separated from its biophysical bases, the space and time of society have become disconnected and completely out of sync with the space and time of nature, resulting in the current ecological crisis. In view of the earth's biophysical limits, these contradictions have become more significant now than ever before, and must be explicitly theorised within political economy in order to move in a more sustainable direction.

By examining the physically necessary relations between extraction and production, and the internal dynamics and differential incorporation of energy in extractive and productive social formations, new insights were gained into the roots of under/over development and environmental destruction. The theory of ecologically unequal exchange was used to take into consideration the many unaccounted and uncompensated environmental externalities and social impacts associated with the extraction of resources and specialisation in the export of primary commodities or pollution intensive products. By considering the net flows of energy and materials between extractive and productive processes, it was shown that specialisation in the export of abundant raw materials and primary commodities in the South, as recommended by the theory of comparative advantage, could lead to short-term "illusory" growth, but that development would be unsustainable in the long-term. A thermodynamic analysis also illustrated how Northern advanced industrial countries are able to maintain a high level of production and consumption, while improving their local environmental standards by shifting environmental costs to the South.

Based on these insights, reliance on the extraction of primary goods as a basis for development was shown to be not only economically unsound, but also socially, politically and ecologically detrimental.

The insights from the dialectic of centre and territory revealed how the current ecological and social crisis is a result of the domination of unsustainable hierarchical centralist tendencies over territorial forms of organisation capable of sustaining themselves locally and within. By expanding the focus of inquiry to the consumptive tendencies of social hierarchies of all types, it challenged not only the character of capitalism and the market, but modern development more generally, and the positivist scientific tradition and modernist assumptions underlying its historical and cultural development. Also, because it moves beyond the structure of closed dualisms, it was shown to facilitate the empowerment of multiple sites of resistance and formation of strategic coalitions by all those marginalised by asymmetric power relations. Its dialectical understanding of social and spatial relations making up a particular place, and the physical flows of energy through institutional spaces, allows it to contextualise a particular place such that it avoids the common weakness within localist approaches to romanticise the local and isolate it from broader economic and political forces effecting it. This territorialist perspective can give support and legitimacy to many initiatives already working to rebuild territorial forces, and promote an understanding which can guide many more.

This now brings us back to our original question of whether a thermodynamically based ecological economics can provide the basis for an alternative understanding and style of development which can promote ecological stability, social sustainability, and supportive socio-political institutions. Turning first to the question of ecological stability, clearly a thermodynamic approach provides essential insights into the conditions necessary to achieve and maintain ecological stability. Ecological economics addresses directly the environmental crisis facing humanity by assessing the scale of human activities necessary to ensure ecological sustainability. It goes beyond the simple internalisation of externalities, to examine the entropic conditions and necessary limits of all physical and economic activity. While neo-classical economics could neither anticipate nor explain the pace of global ecological change, ecological economics provides a nearly complete explanation of increasing global entropy and its environmentally destructive manifestations (Rees 1999a). This more accurate and complete understanding of the interaction between human and environmental systems is essential in order to develop strategies and innovations necessary for achieving ecological sustainability.

To address the criteria for social sustainability, and the requirement for society to satisfy basic standards of material equity and strive for a fair and equitable

distribution of resources for all its inhabitants, the physical insights of ecological economics were combined with an analysis of the social and political dimensions of low-entropy energy appropriation. The thermodynamic understanding, expressed through the theory of ecologically unequal exchange and ecological debt, provided important fresh insights into the causes of uneven development and new perspectives towards resolving this imbalance. By focussing on aspects which have largely been neglected in development debates, an approach drawing on ecological economics is able to side-step hardening conflicts and access a new point of entry into the discussion of free trade, economic specialisation and (un)sustainable development. Such understandings could provide the basis for an approach to sustainability which could ensure a more fair and equitable distribution of resources and wealth.

Finally the requirement for supportive socio-political institutions is taken up within the territorialist approach to political ecology and its expanded understanding of socio-spatial relations. A recognition of the power and control embedded in spatial structures is a first step to uncovering the hidden or naturalised oppressive tendencies within existing socio-political institutions. Such a re-visioned spatial understanding of the institutional roots of oppression and degradation can provide the meeting point for a multiplicity of groups to challenge the status quo and begin creating alternative structures which protect rather than erode territorial values. At the same time, the territorialist understanding of the socially contextual nature of all forms of knowledge and social organisation, and awareness of the many unique and unexplainable aspects of place, ensures a sensitivity to the relationship between universal conditions and particularities of place.

Overall, it appears that a thermodynamically based ecological economics can indeed provide the basis for an alternative understanding and style of development. However in order to ensure that the resulting understanding and practice is emancipatory, ecological economics must be explicitly situated within a broader theoretical framework which recognises the historical development of modern social and spatial structures, and confronts the need for a fundamental restructuring of asymmetrical social and political power relations. Without doing so, the problem of sustainability will continue to be seen as resolvable through value-neutral technical and administrative solutions without challenging the underlying political, social and economic forces which embody and maintain socially and ecologically unsustainable practices (Gale 1998). While there is considerable room for creative initiatives and debate over how to restructure existing social institutions, there is little doubt that fundamental change is required to achieve sustainability.

Evidently, making changes in the direction suggested here would not be a simple task. Changes will need to occur in small steps, and involve a wide variety of strategies at all levels from the local to the global. While the image of a truly sustainable society may seem utopian, there are signs that a new more sustainable direction is emerging. For example, to address the need to reduce material and energy throughput, there are a large number of technical responses from closed loop processes, clean production, and industrial ecology to development of non-fossil forms of energy.[52] There are also detailed strategies for reducing ecologically damaging subsidies and tax provision, and some gradual implementation of carbon taxes in order to promote the shift towards less energy and resource consumption, and more self-reliance.[53] A thermodynamic perspective is also contributing towards increasing awareness and understanding of the superiority of ecological, low tillage, and a variety of traditional farming methods, providing support for alternative approaches to industrial agriculture.

Strategies useful for addressing the concerns of ecologically unequal exchange and flow of resources from North to South include ecological footprint analysis from individual to regional and national levels, ecological rucksack analysis of manufactured products, and material flow accounting at different levels of economic activities. These approaches are gaining increasing recognition, and ecological footprint analysis has been recently promoted by the European Union's Sustainable Cities Initiative. While these approaches are useful in efforts to lower regional or national resource and energy consumption, they are also important to increase awareness of the unequal distribution and exchange of natural resources in international trade relations. There is already wide spread acknowledgement of the historical carbon debt owed by the industrialised countries, and pressure is mounting at international levels for this debt to be redressed. Supplementing this argument with a thermodynamic understanding of unequal exchange and ecological debt could lead towards a revolution in the understanding of "who owes whom" in the world, and what should be done about it.

Among the initiatives working towards the development of territorial forms of self-maintenance are various forms of alternative local economy such as local exchange and trading systems (LETS) and alternative forms of local currency. The resurgence of locally based economic activity in many places represents a new combination of decentralised community control with a sensitivity to the environmental requirements and potentialities of a particular place. There is also a range of initiatives, within both business and community, to replace modern linear hierarchical management structures with circular structures of self-governance (Benello et al. 1989). These include movements for community ownership and control of land, cooperative land banks, worker stock ownership

and profit sharing, and even completely democratised forms of worker ownership and control.[54]

Nevertheless, a main concern still centres on the ways in which current moves toward liberalising world trade erode the long-term potential for making individual economies more sustainable. Also the inherent bias for market institutions to organise the net transfer of energy and materials to world system centres must be addressed. These concerns point to the need for transformations of the global political economy, and concerted efforts to reshape global governance. Institutional changes will be required at all levels, from local reform upward and from global reform downward. Initiatives at national and international levels will include strategies aimed at rebuilding large popular alliances and setting up common targets with sensitivity to different interests. Initiatives at regional and international levels will be required to set up frames for the working of capital markets, the monetary system, and trade which are consistent with the goals of social and ecological sustainability (Amin 1996). While such changes are clearly on the agenda, the shape and substance which they will take is as yet difficult to predict. However, as the territorialist approach argues, centralist institutions will only be legitimised to the extent that they support rather than erode territorial values.

With the current political economy of globalisation spreading out to every corner of the world, it may not appear to be the best time for projecting progressive responses. On the other hand, there are signs that the existing system is in an economic, social and ecological crisis. As Biro and Keil argue: “The current economic and political order is being sustained only through the fictions of credit money, asymmetries in the world trading system, and massive environmental dumping” (Biro & Keil 2000: 89). The first step in challenging this agenda is to challenge its dominant assumptions, reveal their shortcomings and limitations, and expose the hidden forms of power. It is the hope that the thermodynamically based ecological economics perspectives presented here have contributed towards such critical understandings. No easy formulae have been laid out, but each theory has provided some ideas as to the economic, social, or political responses necessary to achieve sustainability. While it may seem unrealistic to expect anything more than occasional reform from existing political and economic structures, it is important to keep in mind that current institutional structures are not “once and for all” but, like structures of all previous era, are constantly evolving under pressure from those who seek to maintain them and those who seek to transform them. In addition, social movements world wide are growing everyday, challenging the dominant dogma and demanding change from its ruling elite. Despite the analytical and political difficulties, the move towards a more just and sustainable development appears

to be on the horizon. As Susan George (2002), a leading figure in the global justice movement, recently expressed:

> "Personally, I have not been so hopeful in decades. The mood is changing. People no longer believe that the unjust world order is inevitable. To Margaret Thatcher's TINA - 'There is no alternative'- they are replying that there are thousands of them. Now it is up to us all… to prove that another world is possible."

Notes

[1] The intention of this brief summary of development theories is to give some indication of the main approaches to the development debate. It does not however do justice to these very comprehensive theories.

[2] The chosen focus on the concept of mutual benefit is but one way of dividing the approaches.

[3] The rejecters of mutual benefit believed that increasing incomes and national economic growth were crucial preconditions for improving standards of living, but these were not regarded as ends in themselves, as was the case with some neo-classical development economists (Martinussen 1997: 37).

[4] See for example, Martinez-Alier 1987

[5] This can be seen in the concept of the "invisible hand" where production in society is seen, in most cases, to be organised in the best interests of all.

[6] Martinez-Alier calls this the "Lawrence Summers" principle, which refers to the leaked memorandum of World Bank economist, Lawrence Summers, who pointed out that "the measurement of the costs of health impairing pollution depends on the foregone earnings from increased morbidity and mortality. From this point of view a given amount of health impairing pollution should be done in the country with the lowest cost, which will be the country with the lowest wages" (Martinez-Alier 1996: 157).

[7] See for example Rees 1999b, Røpke 1999, Jacobs 1997, Martinez Alier 1994, Mayumi and Gowdy 1999.

[8] For a more in depth discussion on the strengths, weaknesses, and applications of the ecological footprint, see "Forum: The Ecological Footprint" in Ecological Economics 32(2000)3.

[9] Organisation for economic development and co-operation which has 30 member countries, and includes all the wealthiest Northern industrialised countries.

[10] Carrying capacity can be defined as the maximum rate of resource consumption and waste discharge that can be sustained indefinitely in a give region (Rees and Wackernagel 1996?)

[11] As revealed by ecological footprint analysis. See Wackernagel (1997) *The ecological footprint of nations* and Wackernagel and Rees (1996) *The Ecological Footprint.*

[12] Adapted from Perkins 2000.

[13] The term "sustainability" is used rather than "sustainable development" to avoid confusion with the many uses and connotations of the latter.

[14] While there are no clear cut lines for where ecological economics ends and other approaches begin, political ecology does not appear to have been a central influence in the development of ecological economics (Constanza et al. 1997; Gale 1998).

[15] The term, biophysical, refers to the physical and biological aspects of nature which are relevant for economics.

[16] See also Martinez-Alier (1987) *Ecological Economics* for a more complete history.

[17] Wind can also be used to generate energy, though it is not in itself a direct source of low-entropy energy. It is however of interest to note that electricity generated by wind has some of the lowest material intensity per unit of electricity delivered (Schmidt-Bleek 2001)

[18] This refers, for example, to the situation in Brazil where sugar cane grown for fuel is displacing rice and beans grown for food (Daly and Cobb 1990: 197).

[19] See also *Ecological Economics* 22(3) 1997- Special Forum: Georgescu-Roegen versus Solow/Stiglitz.

[20] See also Altvater (1998) and Norgaard (1994) for further discussion.

[21] For example, despite increasing fuel efficiency of cars, fuel consumption continues to increase as more cars are used more frequently for longer trips.

[22] While the following theoretical approaches are broadly categorised as political ecology, they could also be categorised as ecological Marxism (in the case of Bunker) or post-modern geography (in the case of M'Gonigle). Furthermore, they are also competing paradigms within ecological economics.

[23] Political economy situates an inquiry of wealth and value in a broader consideration of the power dynamics of social institutions which embody these economic processes.

[24] The second law of thermodynamics actually only deals with isolated systems. However since every open or closed system is a sub-system of some larger isolated system, the second law can also be applied to them. If, for example, the entropy of the open economic sub-system decreases, this has to be compensated for by an increase of entropy in the larger isolated system, such that the total entropy increases, as stated by the second law (Faber 1996: 121).

[25] Unlike the consumption of energy of other animals, which is largely endosomatic and genetically determined, the vast majority of human consumption of energy is for exosomatic consumption, and certainly not determined by genes (Martinez-Alier 1987).

[26] Credit must also be given to governments who were opposed to this agreement though, in explaining its decision to abandon negotiations, France explicitly acknowledged the critical role that environmental groups had played in exposing the negative impacts of the MAI.

[27] It is however becoming apparent that these debt relief measures are not having a significant effect in reducing debt burdens, as all 23 countries who qualified for debt relief are returning to unsustainable debt burdens (Simms 2001).

[28] To some extent, the process of internationalising and transnationalising civil society can itself be understood as an energetic phenomena arising from the globalisation of fossil fordism (Altvater 1998: 35).

[29] See, for example, Peet and Watts (1996) *Liberation Ecologies* or Bryant (1997) *Power, Knowledge, and Political Ecology*.

[30] Dialectical analyses emphasise relations between rather than on individual parts. David Harvey notes: “Dialectical thinking prioritises an understanding of processes, flows, fluxes and relations over the analysis of element, things, structures, and organised systems" (Harvey in Hartmann 1998: 339).

[31] It can be noted that there is suggestion of such a dialectical association between vertical (institutional) and horizontal (geographical) dimensions of the mode of production in the writings of Marx and Engels (Soja 1989: 78).

[32] As concisely defined by Norgaard: atomism assumes that systems are simply the sum of their parts; mechanism assumes that relations between parts of a system are fixed, and changes are reversible; universalism assumes that diverse complex phenomena can be explained by a few underlying universal principles that are unchanging over time and space; objectivism assumes our values, perceptions and actions are apart from the systems we are tying to understand, even social systems; and monisms assumes that our separate disciplinary ways of knowing are merging into a coherent whole (Norgaard 1994b: 214-215).

[33] For example, industrial forestry argue that clear cutting is scientifically justified, because it mimics natural disturbances (i.e. fire); whereas eco-forestry argues that an adaptive nature is dependent on biodiversity, and therefore asserts that cutting techniques and levels should not disturb the composition, structure and function of forest ecosystems. Both are scientifically based, but are rooted in different values and assumptions about nature and economies (M'Gonigle 1999: 21).

[34] There are also abundant studies which suggest that local knowledge may be a complex blend of practice, empiricism and theory.

[35] While energy and matter cannot in themselves cause these developments to occur, they are seen as a necessary prerequisite since none of these development can occur without the conversion of energy and matter (Bunker 1985: 245).

[36] See also Redclift and Benton (ed.) 1994.

[37] Marx also demonstrated an awareness of the significance of time and space for economic processes. However, his critique of political economy does not integrate the kind of understanding revealed through a thermodynamic approach (Altvater 1993: 188).

[38] The staple theory of growth is often attributed to Harold Innis, who demonstrated how the nature of a particular resource, which a peripheral economy exploited as the basis for its development, shaped the character of that economy's development in very concrete ways. However, his critical perspective was forgotten in later neoliberal formulations of it, which adapted the theory to promote the idea of economic growth based on the extraction of natural resources.

[39] Some economists have taken the results of this study so far as to suggest that "the surest way to improve your environment is to become rich" (Beckerman 1992 in Rothman et al. 1998). See Ecological Economics 25(2) 1998 (Special Issue: The Environmental Kuznets Curve) for a fuller discussion of the EKC.

[40] Though in terms of fuels, even dollar-based statistics show that fuels accounted for 46.8% of exports from the South but only 7.8% of those from Northern countries (Hornborg 1998b: 173).

[41] Joint implementation allows corporations or nations to meet their reduction targets by bringing about emission reductions in other countries, where they may be cheaper.

[42] While empirical studies on material flows in international trade are still rather limited, an informative study examining the direct material flows for the EU has been made by Giljum and Hubacek (2001).

[43] See Schmidt-Bleek (2001) for examples of rucksack factors for various materials and products.

[44] Note that ecological footprint or material flow analysis conducted at a national or regional level does not generally reflect per-capital resource use. For example, using material flow analysis, the EU can be shown to have a larger physical trade deficit than, for example, the U.S., even though the per-capita use of materials in the EU is less than that in the U.S. Likewise the ecological footprint of the U.S. appears relatively small when compared with the area of productive land available there, despite the fact that the U.S. has the world's largest per-capita consumption. Environmental space, on the other hand, is calculated on a per-capita bases.

[45] See for example "Ecological debt campaign" (http://www.cosmosvisiones.com) the "Dakar declaration for the total and unconditional cancellation of African and third world debt" (http://www.anotherworldispossible.com/socialforumA_history_dakar.html), or the International Institute for Environment and Development's "World Summit on Sustainable Development" news letter.

[46] In this regard, it is important to mention the recent ruling in Argentina on the foreign debt, which established the responsibility of the civil servants of the dictatorship that contracted it and co-responsibility of international organisation like the IMF, who approved illegal and fraudulent loans. This legal approach, focussing on determining the origins of the debt, the methods employed, the destination of alleged funds, the unilateral modification of conventions, the legitimacy of contracting parties, etc. may be the most effective means of establishing the ultimate illegitimacy of foreign debts in many third world countries (Gaona 2001).
[47] It is at the same time important not to idealise the South nor to ignore regional or local power differentials. These are issues which will be taken up again later.
[48] This is in keeping with the ecological economics theory of consumption.
[49] This restructuring is a complex subject, and is only briefly touched upon here.
[50] This is not to say that the concept of 'class struggle' is incorrect or irrelevant, but rather that it is insufficient as a way of understanding contemporary social conflicts.
[51] The 'end of history' was used to describe the final victory of capitalism and liberal democracy over socialism, following the collapse of the Soviet Union (Fukuyama in M'Gonigle 1999: 15)
[52] As previously discussed, these technical responses are a necessary part of addressing the sustainability problem, but are not on their own sufficient to build a sustainable society. It is therefore important to be aware of both the strengths and limitations of such responses.
[53] See Sachs et al. *Greening the North* for an interesting strategy description.
[54] See Benello et al. *Building Sustainable Communities: Tools and Concepts for Self-Reliant Economic Change* for descriptions and examples of such initiatives.

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